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CONTENTS

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Electrophoretic Studies on Developmental Profiles of Proteins in Haemolymph, Fat Body and Ovary of the Red Cotton Bug *Dysdercus cingulatus* Fabr. (Pyrrhocoridae: Heteroptera)

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ABSTRACT: SDS-PAGE of haemolymph, fat body and ovary proteins of *Dysdercus cingulatus* during the last nymphal instar, and adult was conducted to find out the qualitative changes in protein profile. Comparison of electropherograms of haemolymph from 2 day old male and female adult was performed. Protein pattern showed little difference. But number of protein bands increased in all the three tissues from 0 day 5th instar to the 6th day. Number of protein bands decreased till the last day. Soon after eclosion, number of protein bands in haemolymph decreased suggesting their role in cuticle formation. By contrast ovary and fat body shows a sudden increase of protein bands, after the eclosion.

KEYWORDS: Heteroptera, SDS-PAGE, Protein patterns, *Dysdercus cingulatus*, Lipophorin, apoLp-I, apoLp-II.

INTRODUCTION

During metamorphosis, insects undergo dramatic changes in both form and behavior. Metamorphosis may include radical changes in the structure of internal as well as the more obvious external parts of the body. In Arthropoda moulting is connected with growth and controlled by hormones. While in insects moulting and metamorphosis both depend upon differing concentrations of the same set of hormones; metamorphoric changes can only be manifested as a result of moulting (Penclope, 1970).

Changes which occur in the transformation of nymph to adult may be more or less extensive depending on the degree of difference between the nymph and the adult. During metamorphosis of an insect, process like destruction of certain larval tissues and rejuvenation and remoulding of various tissues into adult one are bound to take place involving synthesis and consumption of the macromolecules as well (Venugopal

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and Dinesh Kumar, 1997). Since proteins are the first biological factors making their manifestation during development (Schmidt and Schwankl, 1975), studies on the tissue specific proteins become morphologically of paramount significance.

The fat body tissue plays a key role in inspect lipid metabolism as this is the site of both lipid storage and mobilization. Number of plasma proteins increases during successive stages of development (Kanost *et al.*, 1990) Haemolymph of insect larva contains several high molecular weight proteins like lipophorins (Shapiro *et al.*, 1988) and arlyphorin (Tefler *et al.*, 1983) in addition to the storage proteins. In insects, lipids are transported by high density lipophorin (HDLP), the major lipoprotein in insect haemolymph, which helps to transport lipids. All these proteins are synthesized in the fat body and released to the haemolymph (Kunkel and Lawler, 1974) to be incorporated later into various organs including ovaries (Rohrkasten and Ferenz, 1985; Valle, 1993). Most of these studies were conducted in holometabolous insects wherein stage specificity is well documented. On the other hand in hemimetabolous insects where stage specificity is less distinct have received less attention so far. The present study was conducted to find out the qualitative changes of proteins in the haemolymph, fat body and ovary of a hemimetabolan bug, *Dysdercus cingulatus* during nymphal-adult transformation.

MATERIALS AND METHODS

Experimental animals

The red cotton bug, *Dysdercus cingulatus* was reared in the laboratory at 28 to 34 °C. The insects allowed to feed on soaked cotton seeds. Eggs were removed every morning and kept in petri-dishes; when hatched, they are transferred to the rearing basins and fed on soaked cotton seeds. Each morning newly moulted adults were isolated which were decided as 0 day old. This method ensured availability of insects of known age when ever required.

Sample preparation

Haemolymph

Haemolymph was collected by cutting antennae and draining the haemolymph in an Eppendrof tube (graduated) with sufficient quantity of phenylthiourea (PTU). Phenylthiourea prevents melanization and coagulation of haemolymph. Haemolymph collected was centrifuged at 12,000 rpm for 10 minute at 4 °C in a refrigerated centrifuge (Universal 16 R Hettich, Zentrifugen Germany) to remove the haemocytes and other debris. Supernatant was taken out and mixed with equal volume of sample buffer. Haemolymph samples were stored at −4 °C until use.

Fat body and ovary

Fat body and ovary were dissected out in Insect Ringer solution, washed in Ringer solution to remove the adhering haemocytes. Wet weight of both the tissues were taken

after blotting. Fifty mg of wet tissues of each fat body and ovary was homogenised separately in glass homogeniser containing 150 μl of homogenising medium (pH 6.8). Centrifuged at 12,000 rpm for 15 minutes at 4 °C. The supernatent was stored at −4 °C.

Protein determination

Protein concentration of ovary, haemolymph and fat body of 0, 2, 4, 6 and 8 days old adults were determined according to the method of Lowry *et al.* (1951). Bovine Serum Albumin served as standard protein

SDS-PAGE

SDS-PAGE (Sodium dodecyl sulphate-polyacrylamide gel) electrophoresis—discontinous and dissociating was carried out according to Laemmli (1970) using 12% acrylamide for separating and 5% for stacking gel. Gel electrophoresis was performed using slab-gel. Each well is loaded with 40 μl sample. A constant current of 60 volts for stacking and 120 volts for running gel were used for 3 hours. Gels were stained overnight in Coomassie brilliant blue R. 250. Gells after run were destained and stored in 7% acetic acid which were photographed later.

Final protein sample

Added equal volume of sample buffer to the supernatant. Final protein samples contained 0.15 M Tris-HCL, pH 6.8, 10% SDS, glycerol, β-mercaptoethanol and traces of bromophenol blue. Samples were boiled for 5 minutes and kept on ice to retain its denatured form. Samples were again centrifuged at 8000 rpm for 5 minutes at 4 °C before application.

Statistical analysis

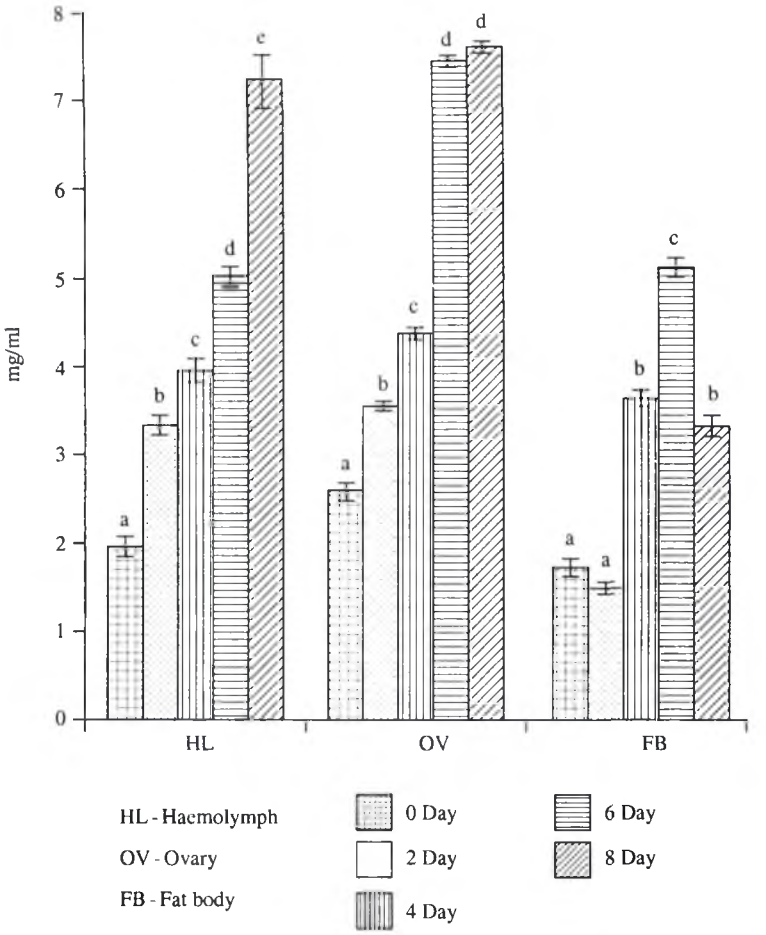
Data were analyzed by one way analysis of variance followd by Duncan's multiple range test using SPSS (Duncan, 1955). Difference was considered significant when $P < 0.05$.

RESULTS

SDS-PAGE was performed on haemolymph and fat body of 5th instar nymphs of different age groups (4 and 6 days old) to compare their protein pattern. SDS-PAGE was also performed on haemolymph, fat body and ovary of adults of various ages (0, 2, 4 and 6 days) to compare their protein pattern. Fat body of male and female 2 day old adult were also carried out.

Protein pattern of haemolymph and fat body of various ages of 5th instar nymph and haemolymph of 2 day male and female adult is shown in Fig. 1(a).

Protein pattern of haemolymph, ovary and fat body of various stages of adult were shown in Fig. 1(b).



Results are expressed as mean ± SD of 10 animals
Groups with different letters are significantly different (P<0.05)

Concentration pattern of total protein in different tissue of *Dysdercus cingulatus*

Protein patterns of these tissues at the nymphal stage reveal presence of some bands that disappear after moulting as well as some bands that newly appear after adult eclosion.

Haemolymph protein pattern

In 4 day old electropherogram of haemolymph 5th instar nymphs showed 18 bands of varying intensities. Of these one band (No. 0 with Rf values 0.35) is very thick and appear to be the major haemolymph protein, while rest of the protein bands are minor bands varying slight variations in their intensities (Fig. 1(a) Lane 1).

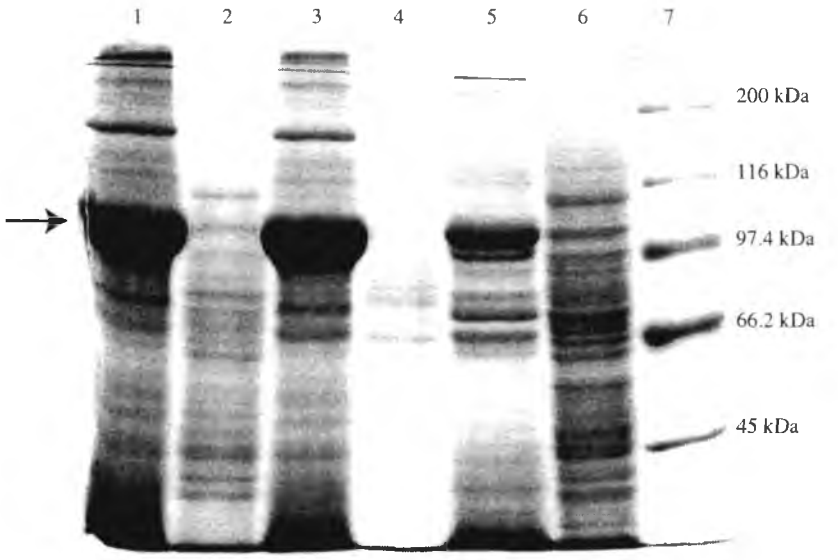


FIGURE 1. Shows the SDS-PAGE patterns of fat body, haemolymph and ovary of *Dysdercus cingulatus* during the nymphal adult transformation. Fig. 1(A) Shows the SDS-PAGE Patterns of the haemolymph, fat body and male and female haemolymph of *Dysdercus cingulatus* (nymph and adult) Lane 1 – nymph haemolymph, Lane 2 – nymph fat body, Lane 3 – nymph haemolymph, Lane 4 – adult male fat body, Lane 5 – adult male haemolymph, Lane 6 – adult female fat body and Lane 7 – molecular weight marker. Arrow indicates the lipophorin subunit.

In 6 day old nymphs haemolymph showed 20 different bands of varying intensities (Fig. 1(a) Lane 3). Of these bands No. 10 (with Rf value 0.35) is very thick and having more intensity than the band of 4 day old nymphs. All the other bands were similar to that of 4 day old nymphs.

In adults haemolymph showed 22 bands altogether with some marked difference from that of the nymphal haemolymph pattern (Fig. 1(a) Lane 5). Band No. 6 (Rf value 0.21) present in the nymphal haemolymph disappeared in the adult. Whereas the intensity of the band No. 10 (with Rf value 0.35) which was prominent in nymphal haemolymph decreased in the adult. Band Nos 13, 14 and 15 (Rf values 0.48, 0.52 and 0.58) respectively became prominent in the haemolymph of the adult. Many new bands appear in the haemolymph of adults.

The 0 day old adult haemolymph showed 18 bands of varying intensities (Fig. 1(b) Lane 1) of which, band No. 8 (Rf value of 0.41) appear to be very thick. This constituted the subunits of the major haemolymph proteins.

The 2 day old adult haemolymph exhibited. 20 bands of varying intensities (Fig. 1(b) Lane 4) of which intensity of band No. 8 (Rf value 0.41) decreased dramatically. However, intensity of other bands are increased compared to that of the haemolymph of 0 day old ones.

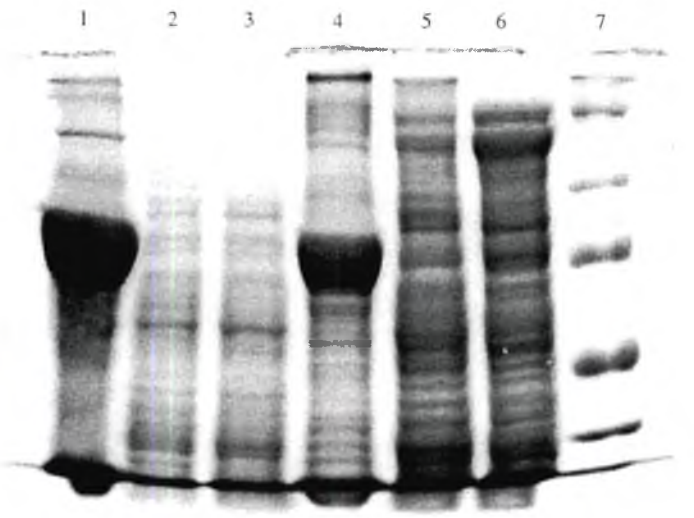


Fig. 1(B) Shows the SDS-PAGE Patterns of the haemolymph, fat body and ovary of 0 and 2 days adult Lane 1 – 0 day haemolymph, Lane 2 – 0 day fat body, Lane 3 – 0 day ovary, Lane 4 – 2 day haemolymph, Lane 5 – 2 day fat body, Lane 6 – 2 day ovary and Lane 7 – Molecular weight marker.

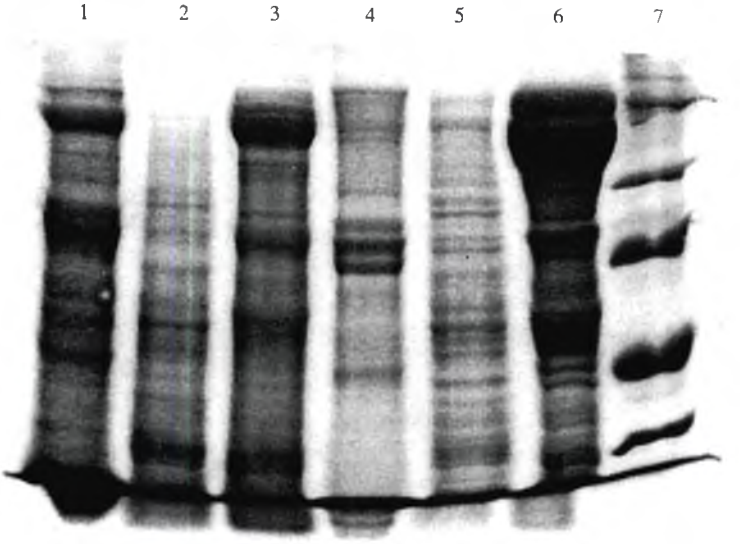


Fig. 1(C) Shows the SDS-PAGE Patterns of the haemolymph, fat body and ovary of 4 and 6 days adult Lane 1 – 4 day haemolymph, Lane 2 – 4 day fat body, Lane 3 – 4 day ovary, Lane 4 – 6 day haemolymph, Lane 5 – 6 day fat body, Lane 6 – 6 day ovary and Lane 7 – Molecular weight marker.

The 4 day old adult haemolymph exhibited 20 bands of varying intensities (Fig. 1(c) Lane 1) out of these band No. 5, 12, 13 and 15 (Rf value 0.15, 0.47, 0.52 and 0.61) respectively are prominent. The intensity of these bands are increasing when compared to the bands of the 2 day old adult haemolymph. But band No. 8 (Rf value of 0.41) is decreased. The 6 day old haemolymph of the adult (Fig. 1(c) Lane 4) showed very dramatic change when compared to haemolymph of 4, 2 and 0 day old ones. In this only 16 bands exhibiting a reduction in number of protein from that of 4, 2 and 0 day ones. Intensity of the major protein bands also decreased in these.

Further comparison of the 4 and 6 days haemolymph, electropherogram revealed that protein bands Nos 5, 12, 13 and 15 (respective Rf values of 0.15, 0.47, 0.52 and 0.61) observed in 4 day old ones disappear on day 6.

After metamorphosis (from 6 day of 5th instar to adult) there occurs a marked reduction in the number of proteins in the haemolymph.

Fat body protein pattern

The fat body of the 4 and 5th instar nymph showed 20 bands. Unlike the haemolymph proteins, different fat body proteins bands is very weak and they do not vary significantly among themselves. However all these proteins exhibited as thin bands. (Fig. 1(a) Lane 2).

Fat body of the male adult (Fig. 1(a) Lane 4) showed a dramatic increase in the number of protein bands when compared to the fat body of the nymph. Fat body of the female adult (Fig. 1(a) Lane 6) showed some difference in the staining intensity of proteins.

The fat body of the 0 day adult (Fig. 1(b) Lane 2) showed a total of 25 bands. Some new bands Nos 23, 24 and 25 (respective Rf value of 0.84, 0.87 and 0.89) appeared.

Fat body of the 2 day adult (Fig. 1(b) Lane 5) showed 24 bands. The intensity of all protein bands increased dramatically when compared to that of 0 day adult. The fat body of 4 day adult (Fig. 1(c) Lane 2) showed a total of only 22 bands showing a decrease in the number of band that of 0 day adult.

The fat body of 6 day old adult (Fig. 1(c) Lane 5) showed an increase in the number upto 30 bands. All bands were prominent and also having almost equal staining intensity.

Thus as development proceeds from 5th instar nymph into the adult, the fat body shows an increase in its protein bands. A total number of 30 protein zones at this adult stage were noticed (Fig. 1(c) Lane 5) out of which band Nos 1, 2, 3, 4, 5, 6, 7, 26, 27 and 28 (respective Rf value: 0.12, 0.15, 0.17, 0.2, 0.22, 0.25, 0.27, 0.82, 0.85 and 0.87) were new proteins.

Ovary protein pattern

The ovary of the 0 day adult (Fig. 1(b) Lane 3) showed a total of 23 bands. Many of these protein have similar mobilization to that of fat body.

Thus ovary of the 2 day adult (Fig. 1(b) Lane 6) showed an increase in the number of protein bands. Protein band 1, 2, 3, 4, 5 and 6 (respective of Rf value 0.11, 0.14,

0.16, 0.18, 0.21 and 0.23) are new proteins. Intensity of protein bands also increased very much as the age increased.

Ovary of the 4 day old adult (Fig. 1(c) Lane 3) showed a dramatic increase in the number and in intensity of proteins. Band Nos 3, 4, 5 and 6 (respective Rf value: 0.16, 0.18, 0.21 and 0.23) showed high increase in their protein concentration.

Ovarian proteins of the 6 day adult (Fig. 1(c) Lane 6) showed high intensity in almost all protein zones. The protein band Nos 1, 2, 3, 4, 5, 6, 12, 13, 14, 18, 19, 20, 29 and 30 (respective Rf value 0.11, 0.14, 0.16, 0.18, 0.21, 0.23, 0.37, 0.40, 0.43, 0.52, 0.55, 0.77, 0.85 and 0.87) showed high intensity.

Thus as the development proceeded, ovary showed the developing of some additional new proteins.

DISCUSSION

Haemolymph protein pattern shows significant reduction in the number of protein zones in 6 day old 5th instar nymph through newly emerged adult. (Fig. 1(a), Lane 3 and Lane 5) such qualitative changing profiles of protein observed during nymphal adult transformation confirms the earlier findings (Maria *et al.*, 1991; Tefler *et al.*, 1983; Rehn and Rolim, 1990).

In adults, haemolymph shows 22 bands altogether with some marked difference from that of the nymphal haemolymph pattern (Fig. 1(a) Lane 5). Band No. 6 present in the nymphal haemolymph disappeared in the adult. Band Nos 13, 14 and 15 respectively became prominent in the haemolymph of adult. Many new bands appear in the haemolymph of adults. It is clear from the electropherogram that during larval-adult transformation, some proteins disappear while some new ones appear, especially in the synthetic phase (Venugopal *et al.*, 1994; Teresa Martinez *et al.*, 1994).

Electropherogram reveals the presence of a major haemolymph protein band as with the same molecular weight of the lipophorin sub unit (80 kDa) (Fig. 1(a), (b) and (c) Lane 7). This agrees with the earlier findings on haemolymph protein. In all the insect species examined so far same type of haemolymph lipoproteins are found (Shapiro *et al.*, 1988; Ryan, 1990; Vander horst, 1990; Soulages and Wells, 1994) for which the name lipophorin was suggested (Chino *et al.*, 1981; Beenakkers *et al.*, 1988). Lipophorin has a protein moiety consisting of three apoprotein, apoLp1 240 kDa and apoLp 11 of 80 kDa and apoLp 111 18 kDa (Rolf Zielger *et al.*, 1999).

Concentration in the protein band Fig. 1(a), band No. 10 (May be lipophorin sub unit) decreases as the age increases suggesting its role as the reusable shuttle in the haemolymph (Beenakkers *et al.*, 1985; Van der Horst *et al.*, 1993) and (Pho *et al.*, 1996). This agrees with earlier findings in the lipd transport mechanism in insect haemolymph (Ryan *et al.*, 2000).

Fat body protein pattern shows emergence of some new proteins in the adult that are absent during the nymphal stage [Fig. 1(a) and (b)]. This suggest that fat body is the centre of synthesising a number of proteins. Proteins are synthesised in the fat body and secreated into the haemolymph (Telfer *et al.*, 1981; Kunkel and Nordin, 1985; Rohrkasten and Ferenz, 1985).

In the present study SDS-PAGE analysis have clearly showed that there are striking differences between the protein pattern of male fat body and female fat body (Fig. 1(a) Lane 4 and 6) fat body protein of female shows new proteins as well as high protein content. This may be due to the presence of female protein like vitellogenin, and may be synthesized in the fat body. This hypothesis was proved in *Periplaneta* (Pan *et al.*, 1969) and *Leucophaea* (Brookes, 1969; Engelmann, 1969) as well as for the month *Hyalophora* (Pan *et al.*, 1969) and the mosquito, *Aedes* (Hagedorn and Judson, 1972). In these cases, newly synthesized vitellogenin was identified by immunoprecipitation of the protiens relating to fat bodies. Immonofluoresence techniques were also employed in the cockroach *Blattella germanica* (Tanaka and Ishizaki, 1979) for visual documentation of the site of vitellogenin synthesis.

As the development proceeds the ovarian protein pattern shows a steady increase in its protein concentration [Fig. 1(b) and (c)]. This increase in the protein intensity may be due to the presence of ovarian protein like vitellogenin (the precursor of the insect egg yolk protein) accumulated in insect eggs during oogenesis (Telfer *et al.*, 1982).

Ovarian protein of the 6 day old adult [Fig. 1(c)] shows high intensity in almost all protein zones (band Nos 1, 2, 3, 4, 5). This may be due to the high accumulation of yolk proteins (Helosia *et al.*, 1997).

It is also observed that a few bands appear during consumption phase. This phenomenon of apprearance and disappearance of protein in a phased manner implicate a genetic control mechanism (Chen, 1978).

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REFERENCES

Beenakkers, A. M. Th., Van der Horst, D. J. and Van Marrewijk, W. J. A. (1985) Insect lipids and lipoproteins, and their role in physiological processes, *Prog. Lipid. Res.* **24**: 19–67.

Beenakkers, A. M. Th., Chino, H. and Law, H. J. (1988) Lipophorin nomenclature, *Insect. Biochem.* **18**: 1–2.

Brookes, V. J. (1969) The induction of yolk protein synthesis in the fat body of an insect. *Leucophaea maderae*, by an analog of the Junenile hormone, *Dev. Biol.* **20**: 459–471.

Chen, P. S. (1978) Protein synthesis in relation to cellular activation and deactivation, In: *Biochemistry of insects*, Morris, Rockstein: (Editor). Academic Press: New York, 146.

Chino, H., Downer, R. G.H., Whyatt, G. R. and Gilbert, L. I. (1981) Lipophorin, a major class of lipophorins of insect hemolymph, *Insect. Biochem.* **11**: 491.

Duncan, D. B. (1955) Multiple range and multiple *F* test, *Biometrics* **11**: 1–42.

Engelmann, F. (1969) Female specific protein biosynthesis controlled by corpus allatum in, *Leucophaea maderae Science NY* **165**: 407–409.

Hagedorn, H. H. and Judson, C. J. (1972) Purification and site of synthehsis of *Aedes aegypiti* yolk protein, *J. Exp. Zool.* **182**: 367–378.

Helosia, S. L., Coelho, Georgia C., Atella, Monica F., Moreira, Katia C., Gondim, and Hatisaburo, Masudo (1997) Lipophorin density variation during oogenesis in *Rhodnius prolixus*, *Arch. Insect Biochem. Physiol.* **35**: 301–313.

Kanost, M. R., Kawooga, J. K., Law, J. H., Ryan, R. O., Heusden, M. C. and Zeigler, R. (1990) Insect haemolymph proteins, In: *Adv Insect. Physiol*, Vol. 22. Academic Press: 299–397.

Kunkel, J. G. and Lawler, D. M. (1974) Larval specific serum proteins in the order Dictyoptera-1. Immunological characterization in larval *Blattella germanica* and cross reaction throughout the order, *Comp. Biochem. Physiol.* **B. 47**: 697–710.

Kunkel, J. G. and Nordin, (1985) Yolk Proteins, In: *Comprehensive Insect Physiolgy, Biochemistry and Pharmacology*, Vol. 1. Kerkut, G. A. and Gilbert, L.: (Editors). Pergamon Press Ltd.: Oxford, 33–111.

Laemmli, U. K. (1970) Cleavage of structural proteins during the assembly of the head of bacteriophage T4, *Nature* **227**: 680–685.

Lowry, O. H., Rosebrough, J. J., Farr, A. L. and Randall, R. J. (1951) Protein measurement with the folin phenol reagant, *J. Biol. Chem.* **193**: 263–275.

Maria, S. Gonzalez, Jose, Luis Soulages and Rodolfo, R. Brenner (1991) Changes in the hemolymph lipophorin and very high density lipoprotein levels during the fifth nymphal and adult stages of *Triatoma infestans*, *Insect Biochem.* **21(6)**: 679–687.

Pan, M. L., Bell, W. J. and Telfer, W. H. (1969) Vitellogenic blood protein synthesis by insect fat body, *Science N.Y.* **165**: 393–394.

Penclope, M. Jekin (1970) Control of Growth and metamorphosis, In: *Part II of Animal Hormones Page 145*.

Pho, D. B., Pennanei'h, M. and Jallon, J. M. (1996) Purification of adult *Drosophila melanogaster* lipophorin and its role in hydrocarbon transport, *Arch. Insect Biochem. Physiol.* **31**: 289–303.

Rhen, K. G. and Rolim, A. L.R (1990) Purification and properties of a storage protein from the haemolymph of *Rhodnius prolixus*, *Insect Biochem.* **20**: 195–201.

Rohrkasten, A. and Ferenz, H. J. (1985) *In vitro* study of selective endocytosis of vitellogenin by locust oocytes. Roux's, *Arch. Dev. Biol.* **194**: 411–416.

Rolf Ziegler, Lesile A., Willingham, Diane L., Engler, Kenneth J., Tolman, David Bellows, Dick, J. Vander Horst, Gloria, M. Yepij plasceneia and John, H. Law (1999) A novel lipoprotein from the haemolymph of the cochineal insect, *Dactylophins confuses*, *Eur. J. Biochem.* **261**: 285–290.

Ryan, R. O. (1990) Dynamics of insect lipophorin metabolism, *J. Lipid Res.* **31**: 1725–1739.

Ryan, R. O. and Dick, J. (2000) Lipid transport Biochemistry and its role in energy production, *Ann. Rev. Entomol.* **45**: 233–260.

Schmidt, W. and Schwankl, (1975) Changes in haemolymph proteins during the metamorphosis of both sexes and castes of polygynous Formica rufa, *Comp. Biochem. Physiol.* **B52**: 305–380.

Shapiro, J. P., Law, J. H. and Wells, M. A. (1988) Lipid transport in insects, *Ann. Rev. Entomol.* **33**: 297–318.

Soulages, J. L. and Wells, M. A. (1994) Lipophorin: The structure of an insect lipoprotein and its role in lipid transport, *Adv. Protein Chem.* **45**: 371–415.

Tanaka, A. and Ishizaki, H. (1979) Immunochemical detection of vitellogenin in the ovary and fat body during a reproductive cycle of the cockroach, *Blattella germanica. Del. Growth Diff.* **16**: 247–255.

Telfer, W. H., Keim, P. S. and Law, J. H. (1983) Arylphorin, a new protein from *Hyalophora cecropia*, comparisons with calliphorin and manducin, *Insect Biochem.* **13**: 601–613.

Telfer, W. H., Hucbnor, E. and Smith, D. S. (1982) The cell biology of vitellogenic follicles in *Hyalophora* and *Rhodnius*, In: *Insect Ultrastructure*, Vol. I. King, R. C., Akai, and H.,: (Editors). Plenum Press: New York, 118–149.

Telfer, W. H., Rubenstein, E. and Pan, M. L. (1981) *In Regulation of Insect Development and Behavior*, Sehnal, F., Zabza, A., Menn, J. J. and Cymborowski, B.: (Editors). Wroclaw Technical University Press: Wroclaw, Poland, 637–654.

Teresa, Martines and Diana, E. Wheeler (1994) Storage proteins in adult ants *Camponotus festinatus*: Roles in colony founding by Queens in Larval Rearing by workers, *J. Insect Physiol.* **40(8)**: 723–729.

Valle, D. (1993) Vitellogenesis in insects and other groups A review, *Mem. Inst. Oswaldo. Cruz.* **88**: 1–26.

Van der Horst, D. J. (1990) Lipid transport function of lipoproteins in flying insects, *Biochem. Biophys Acta* **1047**: 195–211.

Van der Horst, D. J., Weers, P. M.M. and Van Marrewijk, J. A. (1993) Lipoproteins and lipid transport, In: *Insect Lipids: Chemistry, Biochemistry and Biology*, Samuelson, D. W.S. and Nelson, D.: (Editors). University of Nebraska Press: Lincoln, NB, and London, 1–24.

Venugopal, K. J. and Dinesh Kumar, (1997) Electrophoretic studies on Developmental profiles of protein in Haemolymph, fat body and ovary of the Red Cotton Bug, *Dysdercus koenigii Entomon* **22 (3 & 4)**: 185–191.

Venugopal, K. J., Dinesh Kumar, and Singh, S. A. (1994) Developmental studies on proteins from haemolymph fat body and ovary of a phytophagous bug, *Dysdercus koenigii* (Heteroptera: Pyrrhocoridae), *Biochem. Arch.* **10(4)**: 297–303.

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Effect of Leguminous Host Plants on Fecundity and Longevity of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae)

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ABSTRACT: Laboratory bioassays were conducted to evaluate the effect of larval food, i.e. leaves and flower buds of four leguminous plants, *viz.*, chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* Millsp.), blackgram (*Vigna mungo* L.), and cowpea (*Vigna unguiculata* Walp.) on the pre-oviposition period, fecundity and longevity of *Helicoverpa armigera* females. Pre-oviposition period of females reared during larval stages on chickpea leaves was significantly shorter compared to those reared on leaves of other host plants. The fecundity of females fed during larval stages on cowpea and pigeonpea leaves was statistically not different. However, it was significantly higher ($P < 0.01$) than the fecundity of females reared on blackgram and chickpea leaves. Leaves of different test plants did not influence longevity of females. The fecundity indices of females reared on cowpea (56.21) and pigeonpea leaves (44.73) were statistically similar, but significantly higher compared to those reared on blackgram (39.38) and chickpea (37.89) leaves. No significant difference was observed in the pre-oviposition period of females, fed on flower buds of different leguminous plants during larval stages. The fecundity of females reared on the pigeonpea flower buds was significantly higher compared to other test buds. Egg production and longevity of adults reared on chickpea flower buds were significantly lower ($P < 0.01$) compared to other test buds. The fecundity index of females was highest for those fed on pigeonpea buds. This was almost twice greater than fecundity index of females reared on cowpea, blackgram and chickpea buds. These observations indicate that leaves of pigeonpea and cowpea, and flower buds of pigeonpea contain nutritional factors, which promote egg-production. These factors may be present in suboptimal levels in the leaves and buds of other test plants, which account for low egg-production.

KEYWORDS: *Helicoverpa armigera*, pre-oviposition period, fecundity, longevity, legumes, host selection.

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INTRODUCTION

The gram podborer, *Helicoverpa armigera* (Hübner), is a serious pest of more than 200 species of plants (Manjunath *et al.*, 1985; Zalucki *et al.*, 1994), including economically important crops, like cotton, tomato, sorghum, groundnut, chickpea, pigeonpea, sunflower, maize, etc. This insect has wide geographical distribution, occurring throughout Africa, central and south-east Asia, southern Europe, the Middle East, eastern and northern Australia, New Zealand and many Pacific Islands (Fitt, 1989). High polyphagy, mobility and fecundity are major factors contributing to the serious pest status of *H. armigera* (Fitt, 1989). The estimates of annual economic loss due to this pest include, US $300 million for chickpea and pigeonpea in India (Reed and Pawar, 1982), US $300 million for pigeonpea worldwide (International Crop Research Institute for the Semi-Arid Tropics , 1994), and US $1500 million for cotton worldwide (International Cotton Advisory Committee, 1998).

There are several reports about the role of mating, adult nutrition, and temperature on the fecundity and longevity of *H. armigera* females (Singh and Rembold, 1989; Jallow and Zalucki, 1998; Hou and Sheng, 1999). There are also reports about the fecundity and longevity of *H. armigera* females fed during larval stages on different host plants (Doss, 1979; Dhandapani and Balasubramanian, 1980; Dubey *et al.*, 1981; Bilapate, 1987; Katole, 1992; Shanower *et al.*, 1997), or different parts of a plant (Goyal and Rathore, 1988; Sison and Shanower, 1994; Kumar *et al.*, 1995; Zhuan *et al.*, 1998). However, there is hardly any comparative information about fecundity and longevity of *H. armigera* females reared on different leguminous crops. The present study attempts to compare and determine the effects of larval host plants, i.e. chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* Millsp.), blackgram (*Vigna mungo* L.) and cowpea (*Vigna unguiculata* Walp.), on the pre-oviposition period, fecundity and longevity of gram podborer females.

MATERIALS AND METHODS

Helicoverpa armigera (Hübner) culture was maintained in the insectary by the method described by Singh and Rembold (1992). Seeds of test plants were obtained from Indian Agricultural Research Institute, New Delhi. The test varieties of leguminous plants included chickpea (PUSA 256), pigeonpea (UPAS 120), cowpea (PUSA KOMAL), and blackgram (T9). These were grown in the field plots of Zoology Department, Delhi University under pesticide free condition. The neonate larvae were reared individually on *ad libitum* supply of leaves and flower buds of each test plant till pupation. The larvae were transferred everyday to sterilized rearing containers (7 × 7 cm), provisioned with freshly excised plant parts. Male and female pupae were separated, and kept in separate containers. Adults ecloding from pupae were kept singly in round perspex containers (7 × 7 cm), and were provided 10% honey solution in a plastic stopper to facilitate feeding. The male and female moths were paired (1 : 1) on third night after emergence in individual mating jars, which also served as oviposition jar. The oviposition jar consisted of round glass jar (11.5 × 9 cm). A strip of tissue paper

was placed on the sides of the jar in such a way that it hanged along the internal wall of the jar. The tissue paper lining at the bottom and side walls of test jars provided surface for perching as well as egg laying. The mouth of the jar was covered with muslin cloth, which was held tightly with a rubber band. This prevented escape of the moths from the jars and allowed adequate ventilation.

The test jars were kept inside BOD incubator at 27° ± 1 °C, 65 ± 5% R.H. and 14L : 10D photoperiod. The moths were transferred to clean oviposition jars everyday. Eggs laid on tissue paper strips and walls of the jars were counted daily until the female died. After death, the female moth was dissected and number of eggs present inside the ovary was counted. Twelve females were tested for each larval food. The insects were grouped as replicate, and each replicate consisted responses of three females.

The total number of eggs produced by individual female included the 'number of eggs laid by the females through out their life as well as those remaining inside the body at death'. Since variation in total egg-production may also be due to differences in survival period of females, their basic fecundity was examined in terms of 'Fecundity Index'. This was calculated as the ratio between 'total number of eggs produced' and the 'survival period'. The data were subjected to one way ANOVA (Snedecor and Cochran, 1967) followed by Duncan's Multiple Range Test (Duncan, 1955) for comparing differences among means.

RESULTS

Effects of leaves on egg-production

Larval food had significant effect on the egg-production of *H. armigera* females. The mean number of eggs produced by a female was highest and lowest for those fed during larval stages on cowpea and chickpea leaves respectively (Table 1). Average fecundity of females fed during larval stages on cowpea leaves and pigeonpea leaves were statistically not different. However, this was significantly higher than the fecundity of females reared on blackgram and chickpea leaves. Moreover, the females reared during larval stages on chickpea and blackgram leaves oviposited identical number of eggs (Table 1).

Pre-oviposition period of *H. armigera* females reared on different host plants differed significantly (Table 1). This period was shortest for females fed on chickpea leaves and longest for those fed on cowpea leaves. Pre-oviposition period of females reared on chickpea leaves was identical to those reared on pigeonpea and blackgram leaves. However, pre-oviposition period of the females fed on chickpea leaves was significantly shorter than those fed on cowpea leaves. Larval food of test plants did not significantly influence longevity of females or males.

The fecundity indices of *H. armigera* females, reared during larval stages on the leaves of four host plants were found to vary. The fecundity indices of females reared on cowpea and pigeonpea leaves were not significantly different. However, this was statistically higher ($P < 0.05$) than the fecundity indices of females reared on chickpea and blackgram leaves (Fig. 1).

TABLE 1. Effect of larval food of leaves and flower buds of leguminous plants on the pre-oviposition period, fecundity and longevity of *H. armigera*

Larval food	Preoviposition period (days)(mean ± SD)	Adult longevity (days)(mean ± SD)		Fecundity (average number of eggs) produced per female) (mean ± SD)
		Females	Males	
Leaves				
Chickpea	3.83 ± 0.43^{a}	14.50 ± 2.64^{a}	13.76 ± 3.50^{a}	545.0 ± 113^{a}
Pigeonpea	4.83 ± 0.43^{ab}	16.83 ± 2.38^{a}	15.41 ± 1.69^{a}	746.0 ± 132^{ab}
Blackgram	4.83 ± 1.10^{ab}	15.93 ± 1.76^{a}	12.78 ± 1.69^{a}	616.0 ± 67^{a}
Cowpea	5.33 ± 0.98^{b}	15.17 ± 2.12^{a}	12.92 ± 1.37^{a}	848.0 ± 135^{b}
Flower buds				
Chickpea	3.67 ± 1.30^{a}	8.34 ± 1.54^{a}	5.42 ± 2.42^{a}	229.3 ± 34.7^{a}
Pigeonpea	4.00 ± 0.77^{a}	16.90 ± 0.95^{b}	20.24 ± 4.71^{b}	1179.0 ± 63.5^{b}
Blackgram	4.63 ± 0.63^{a}	13.13 ± 1.75^{c}	17.00 ± 3.27^{bc}	379.5 ± 88.0^{c}
Cowpea	4.50 ± 1.00^{a}	17.83 ± 1.03^{bd}	14.43 ± 1.59^{cd}	635.0 ± 157^{d}

Means in a column in each box not followed by same superscript differ significantly ($P < 0.05$; DMRT).

Effects of flower buds on egg-production

Feeding the larvae on flower buds of different test plants had significant effect on the fecundity of *H. armigera* females. The fecundity of females reared during larval stages on pigeonpea buds was five times higher than that reared on chickpea. The fecundity of females reared on cowpea and blackgram flower buds was half and one-third respectively compared to that fed on pigeonpea buds (Table 1).

Pre-oviposition periods of *H. armigera* females, reared during larval stages on flower buds of different test plants were not statistically different. Flower buds had significant effect on the longevity of *H. armigera* females and males (Table 1). The longevity of females reared during larval stages on chickpea flower buds was significantly shorter than those fed on pigeonpea, cowpea and blackgram buds ($P < 0.001$). Survival periods of females on pigeonpea and cowpea buds were not statistically different. However, these periods were significantly longer compared to those fed on blackgram and chickpea buds. Survival periods of females reared on pigeonpea and cowpea buds were almost two-fold longer than those reared on chickpea buds. The longevity of males reared during larval stages on blackgram was statistically equal to the males reared on pigeonpea and cowpea buds, but significantly longer than those reared on chickpea buds.

The highest fecundity index was recorded for females reared on pigeonpea flower buds (Fig. 1). This was almost double compared to the fecundity index of females reared during larval stages on cowpea, blackgram and chickpea buds. Fecundity

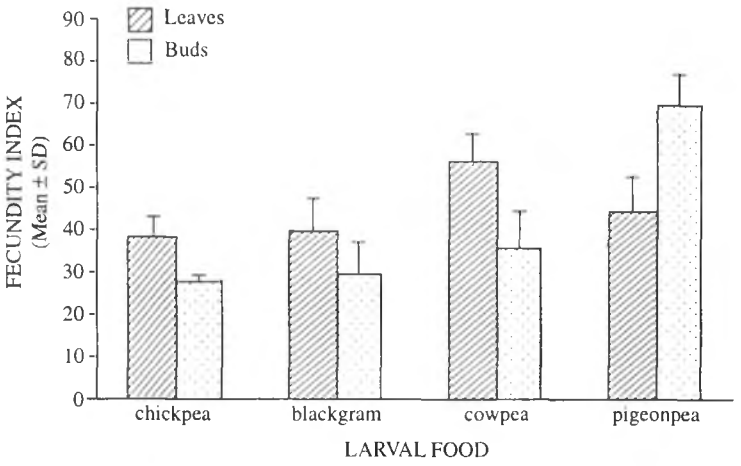

FIGURE 1. Fecundity indices of *H. armigera* females, fed on the leaves and flower buds of leguminous crops during larval stages.

indices of females reared on chickpea, blackgram and cowpea flower buds were statistically similar to each other (Fig. 1).

DISCUSSION

Larval food plays an important role in the establishment of insect population on a plant surface. These determine build-up of population by influencing growth and development during larval stage and, longevity as well as fecundity during adult stage (Saxena, 1969). In the present study, significant effect of different leguminous leaves on the fecundity of *H. armigera* was evident. The fecundity of *H. armigera* reared on pigeonpea and cowpea leaves was higher compared to those reared on other host plant leaves. Isley (1935) also observed that the effect of larval food on the fecundity was more pronounced than any other factors in cotton bollworm. However, fecundity of *H. armigera* female fed on leaves of different species of pigeonpea (Shanower *et al.*, 1997), and foliages of different cultivars of cotton (Kumar *et al.*, 1995) did not vary significantly.

Significant differences in the pre-oviposition period of *H. armigera* moths, reared on different host plant leaves, have been observed. However, Kumar *et al.* (1995) did not observe differences in the pre-oviposition period of *H. armigera* females, fed on different parts of cotton plant. Nadgauda and Pitre (1983) also reported statistically insignificant differences in the pre-oviposition period of *Heliothis virescens* reared on cotton, soybean and artificial diet. Longevity of *H. armigera* reared on different test leaves was found to be more or less similar. This is in consistent with the observation made by Nadgauda and Pitre (1983). They found that the larval food had no influence on the longevity of *H. virescens* and *H. zea* adults. However, Sison and Shanower

(1994) observed significant differences in the longevity of *H. armigera* moths, reared on different genotypes of pigeonpea.

Flower buds of different leguminous plants had significant effect on the fecundity of gram podborer females. Pigeonpea flower buds promoted higher egg-production of females compared to chickpea flower buds. However, fecundity of *H. armigera* females reared during larval stages on water soaked pigeonpea and chickpea seeds was found to be statistically similar (Tripathi and Singh, 1989). Doss (1979) observed significant differences in the fecundity of *H. armigera* females reared on reproductive parts of different plants, i.e. cotton bolls, soybean pods, tomato fruits and ear of corn. Effect of larval food on the fecundity of *H. armigera* females was also reported by Kumar *et al.* (1995). They observed significantly higher fecundity on bolls compared to squares and leaves of cotton. Zhuan *et al.* (1998) observed significantly higher fecundity in *H. armigera* females reared during larval stages on silk compared to leaves and kernel of maize. Flower buds of different legumes had no effect on pre-oviposition period, but significant effect on longevity of *H. armigera* adults. Significant differences in the longevity of *H. armigera* females fed on leaves, squares and bolls of cotton was also reported by Kumar *et al.* (1995). Larval food of soybean pods, cotton bolls, and tomato fruits cause significant differences in the longevity of gram podborer females, observed Doss (1979).

Helicoverpa armigera is a major pest of chickpea and pigeonpea, and minor pest of cowpea and blackgram Sachan (1992). Larval food of flower buds of pigeonpea was more suitable in promoting egg-production in *H. armigera* as compared to leaves. Conversely, larval food of chickpea leaves promoted higher egg-production in females compared to flower buds. Survival of larvae has also been observed high on pigeonpea flower buds (Mullick and Singh, 2000) and chickpea leaves (Singh and Mullick, 1997). These positive factors in the flower buds of pigeonpea and leaves of chickpea ultimately promote population build-up of *H. armigera* by contributing higher egg-production in subsequent generation. Lower fecundity of gram podborer females, fed on leaves of pigeonpea and flower buds of chickpea may, be due to either presence of certain antibiotic factors or absence of essential nutrients in these surfaces. The significant variations in fecundity, pre-oviposition period and longevity of *H. armigera* on different plant surfaces suggest differences in the nutritional and biochemical constituents of leguminous crops. However, further study is needed to isolate and characterize these factors, which will help to understand the mechanisms of its establishment on the plant surface.

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REFERENCES

Bilapate, G. G. (1987) Investigation on *Heliothis armigera* (Hubner) in Marathwada—XIII: Growth and development on different host plants, *J. Maharastra Agric. Univ.* **13**: 186–188.

Dhandapani, N. and Balasubramanian, M. (1980) Effect of different food plants on the development and reproduction of *Heliothis armigera, (Hbn.) Experientia* **36**: 930–931.

Doss, S. A. (1979) Effect of host plants on some biological aspects of the bollworm, *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae), *Z. Pflkrankh. Pflschutz.* **86**: 143–147.

Dubey, A. K., Mishra, U. S. and Dixit, S. A. (1981) Effects of host plants on the developmental stages of gram podborer, *Heliothis armigera* (Hübner), *Indian J. Ent.* **43**: 178–182.

Duncan, D. B. (1955) Multiple range and multiple *F* test, *Biometrics* **11**: 1–42.

Fitt, G. P. (1989) The ecology of *Heliothis* species in relation to agroecosystems, *Annu. Rev. Ent.* **34**: 17–52.

Goyal, S. P. and Rathore, V. S. (1988) Patterns of insect plant relationships determining susceptibility of different hosts to *Heliothis armigera* (Hübner), *Indian J. Ent.* **50**: 193–201.

Hou, M. L. and Sheng, C. E. (1999) Fecundity and longevity of *H. armigera*: Effects of multiple mating, *J. Econ. Ent.* **92(3)**: 569–573.

International Cotton Advisory Committee (1998) Cotton World Statistics, ICAC: Washington.

International Crop Research Institute for the Semi-Arid Tropics (1994) *The Medium Term Plan*, Vol. 3. ICRISAT: Andhra Pradesh, India.

Isley, D. (1935) Relation of hosts to abundance of cotton bollworm, *Arkansas Agric. Stn. Bull.* **320**: 1–30.

Jallow, M. F. A. and Zalucki, M. P. (1998) Effects of egg load on the host selection behavior of *H. armigera*, *Aust. J. Zool.* **45(3)**: 291–299.

Kumar, V., Yadav, L. S., Verma, A. N., Kashyap, R. K. and Kumar, R. (1995) Development and reproductive potential of *Helicoverpa armigera* (Hubner) on various plant parts of cotton cultivars/hybrid, *Insect Sci. Applic.* **16(2)**: 199–205.

Katole, S. R. (1992) Effect of larval food plants on the development and reproduction of *Heliothis armigera*, *Comp. Physiol. Ecol.* **17(3)**: 97–107.

Manjunath, T. M., Bhatnagar, V. S., Pawar, C. S. and Sitananthan, S. (1985) Economic importance of *Heliothis* sp. in India and an assessment of their natural enemies and host plants, In: *Proceedings of Workshop on Biological Control of Heliothis*, International Crop Research Institute for the Semi-Arid Tropics: Andhra Pradesh, India, 11–15.

Mullick, S. and Singh, A. K. (2000) Suitability of flower buds and pods of leguminous crops for development of *Helicoverpa armigera* (Hbn.) (Lepidoptera: Noctuidae), In: *Abstracts of 3rd International Crop Science Congress*, 17–22 August 2000. Hamburg: Germany, 92.

Nadgauda, D. and Pitre, N. (1983) Development, fecundity, and longevity of the tobacco budworm (Lepidoptera: Noctuidae) fed soybean, cotton, and artificial diet at three temperatures, *Environ. Entomol.* **12**: 582–586.

Reed, W. and Pawar, C. S. (1982) *Heliothis*: A global problem, In: *Proceedings of International Workshop on Heliothis Management*, International Crop Research Institute for the Semi-Arid Tropics: Andhra Pradesh, India, 9–14.

Sachan, J. N. (1992) Present status of *Helicoverpa armigera* in pulses and strategies for its management, In: *Helicoverpa Management: Current Status and Future Strategies*, 30–31st August 1990. Sachan, J. N.: (Editor). Indian Institute of Pulses Research: Kanpur, India, 7–23.

Saxena, K. N. (1969) Patterns of insect-plant relationships determining susceptibility or resistance of different plants to an insect, *Ent. Exp. Appl.* **12**: 751–766.

Shanower, T. G., Yoshida, M. and Peter, A. J. (1997) Survival, growth, fecundity and behavior of *H. armigera* (Lep: Noc) on pigeonpea and two wild *Cajanus* species, *J. Econ. Ent.* **90(3)**: 837–841.

Singh, A. K. and Rembold, H. (1989) Oviposition behaviour of *Heliothis armigera* (Lepidoptera: Noctuidae) in relation to the day-night cycle, *Insect Sci. Applic.* **10(3)**: 393–400.

Singh, A. K. and Rembold, H. (1992) Maintenance of the cotton bollworm, *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) in laboratory culture, *I. Rearing on synthetic diet. Insect Sci. Applic.* **13**: 333–338.

Singh, A. K. and Mullick, S. (1997) Effect of leguminous plants on the growth and development of gram pod borer, *Helicoverpa armigera*, *Indian J. Ent.* **59(2)**: 209–214.

Sison, M. L. and Shanower, T. G. (1994) Development and survival of *Heliothis armigera* (Lepidoptera: Noctuidae) on short duration pigeonpea, *J. Econ. Ent.* **32**: 1749–1753.

Snedecor, G. W. and Cochran, W. G. (1967) *Statistical Methods*, The Iowa State University Press: USA.

Tripathi, S. R. and Singh, R. (1989) Effect of different pulses on development, growth and reproduction of *Heliothis armigera* (Hbn.) (Lepidoptera: Noctuidae), *Insect Sci. Applic.* **10(2)**: 145–148.

Zalucki, M. P., Murray, D. A. H., Gregg, P. C., Fitt, G. P., Twine, P. H. and Jones, C. (1994) Ecology of *Helicoverpa armigera* (Hübner) and *Helicoverpa punctigera* in the inland of Australia: Larval sampling and host plant relationships during winter and spring, *Aust. J. Zool.* **42**: 329–346.

Zhuan, H. Y., Duan, J. Z., Dong, Y. X. and Xing, X. B. (1998) Comparision of development and fecundity of the cotton bollworm, *Helicoverpa armigera* (Hübner), feeding on different organs of maize, *J. Nanjing Agric. Univ.* **21(4)**: 47–51.

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Leafhopper Fauna Associated with Vegetable Crops of Andhra Pradesh in India

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ABSTRACT: Seventeen leafhoppers associated with vegetable crops like brinjal, okra, tomato, beans, amaranthus, spinach, cabbage, cauliflower, coccinia, cowpea and gourds from different agroclimatic zones of Andhra Pradesh state in India are collected and identified. They are *Austroagallia bifurcata* Sawai Singh and Gill, *Batracomorphus angustatus* (Osborn), *Balclutha incisa* (Matsumura), *B. pararubrostriata* Ramasubbarao and Ramakrishnan, *B. saltuella* (Kirschbaum) *Cicadulina (Cicadulina) bipunctata* (Melichar), *Deltocephalus (Deltocephalus) vulgaris* Dash and Viraktamath. *D. (Recilia) tareni* Dash and Viraktamath, *Exitianus indicus* (Distant), *Amrasca biguttula biguttula* (Ishida), *Empoasca (Empoasca)* motti Pruthi, *E. punjabensis punjabensis* Pruthi, E. (Distantasca) terminalis Distant, *Empoascanara defecta* Dworakowska, *Seriana jaina* (Distant), *Hecalus porrectus* (Walker) and *Hishimonus phycitis* (Distant). A key for distinguishing these leafhoppers has been provided. Among the leafhoppers identified, which attained pest status are *A. biguttula biguttula* on brinjal and okra, *E. (Empoasca) motti* on clusterbeans and coccinia and *H. phycitis* (Distant) on brinjal.

KEYWORDS: leafhoppers, Cicadellidae, vegetables, key to species.

INTRODUCTION

In India Vegetables occupy only about 1.2% of total area under cultivation and the total production is about 16 MT/year which is rather very low. Hence emphasis has been given to increase the yields of vegetable crops by introducing high yielding varieties by using modern technology of breeding and with suitable agronomic practices. The new high yielding varieties and hybrids generally are susceptible to the insect pests and due to changes in agronomic practices some minor and unknown pests assume the status of major pests. Among the various insect pests that have been causing damage to the vegetable crops in Andhra Pradesh, the sap sucking leafhoppers have long been known to be pests either by direct feeding or through transmitting virus and virus like diseases.

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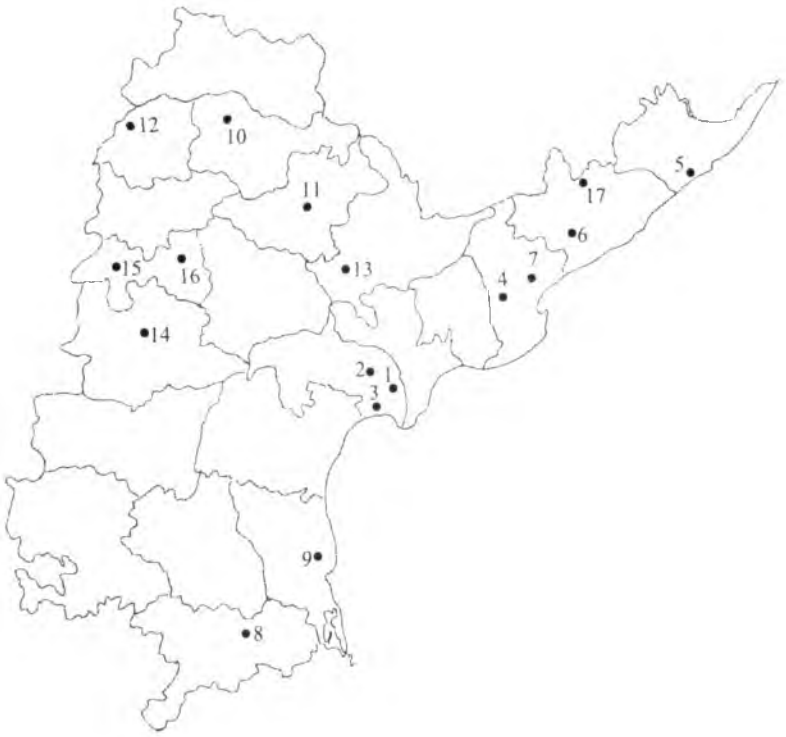

Plate 1: Map showing areas surveyed for collection of leafhoppers on vegetables crops in Andhra Pradesh. 1. Tenali, 2. Guntur, 3. Bapatla, 4. Rajahmundry, 5. Srikakulam, 6. Anakapalli, 7. Peddapuram, 8. Tirupati, 9. Nellore, 10. Jagtial, 11. Warangal, 12. Rudrur, 13. Khammam, 14. Palem, 15. Rangareddy, 16. Hyderabad, 17. Arakuvalley.

Leafhoppers belonging to the family Cicadellidae are the members of Auchenorrhynchous: Homoptera. These are small, wedge shaped insects of various forms, colours and sizes and are distinguished from other Auchenorrhyncha by having one or more rows of small spines extending the length of hind tibiae (Plate 2E). The effective management of pest species damaging the crop cannot be undertaken without accurate identification. The literature dealing with the identification and taxonomy of insects is scattered in many journals and monographs published over many years and in many languages. Many of these works are very difficult to obtain. The broad objective of these studies is to survey and collection, identification of leafhoppers found on vegetables in Andhra Pradesh and to provide keys to enable accurate identification of common species.

MATERIALS AND METHODS

The present investigation on leafhopper fauna associated with vegetable crops in Andhra Pradesh was conducted at Agricultural College, Aswaraopet, Khammam

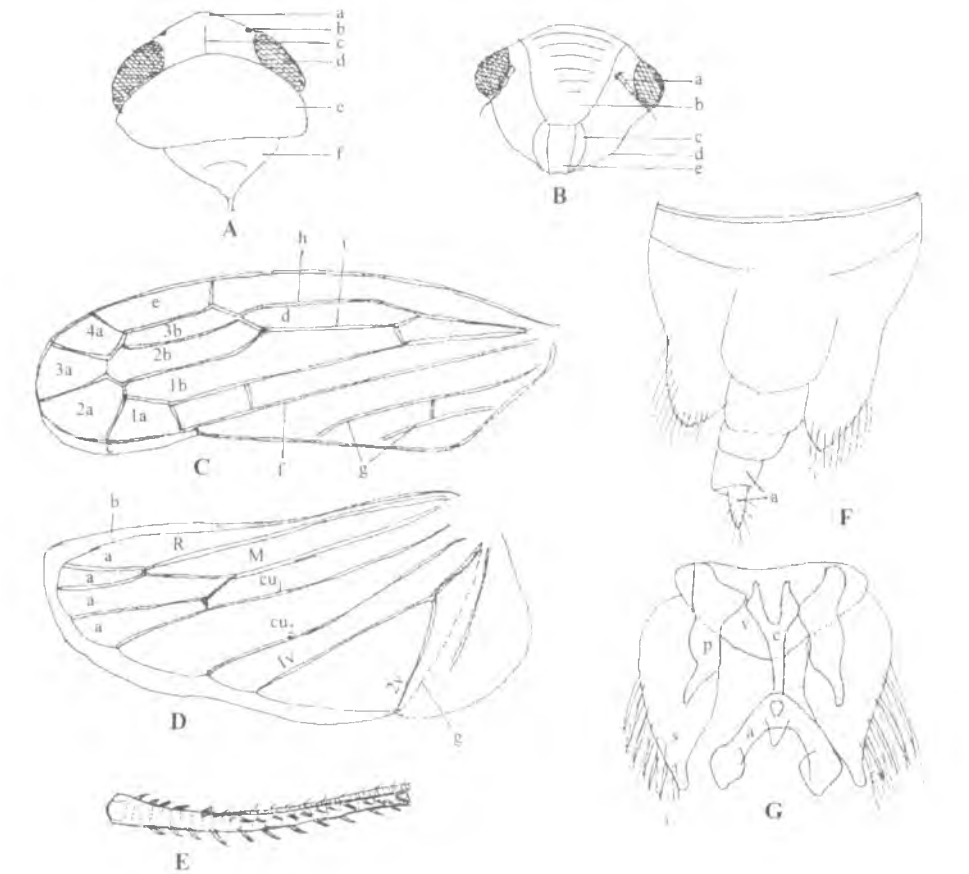

Plate 2: Different body parts of leafhopper. (A) Head and thorax, dorsal view: a. Vertex, b. Ocellus, c. Coronal suture, d. Eye, e. Pronotum, f. Scutellum. (B) Face: a. Antenna, b. Clypeus, c. Lorum, d. Gena, e. Clypellus. (C) Forewing: 1a, 2a, 3a & 4a. 1st, 2nd, 3rd & 4th apical cells; 1b, 2b & 3b. Inner, Central & Outer anteapical cells; c. Appendix, d. Discal cell, e. Costal cell, f. Claval suture, g. Claval veins, h. Radius, i. Media. (D) Hindwing: a. Apical cells, b. Costal margin, R. Radius, M. Media, Cu1 & Cu2. Cubitus 1 & 2, 1V & 2V. Vannal veins 1 & 2, g. Jugal fold. (E) Hind tibia with rows of spines. (F) Male genitalia – Pygofer, dorsal view: a. Anal tube. (G) Male genitalia (Pygofer removed): v. Valve, s. Subgenital plate, c. Connective, p. Paramere (Style), a. Aedeagus.

district as head quarters during 1995–97. The leafhopper collections were made intensively in different vegetable crops like brinjal, okra, tomato, beans, amaranthus, spinach, cabbage, cauliflower, coccinia, cowpea, gourds etc., in different agro-climatic zones of the state (Plate 1). About fifteen to and net-sweepings were taken each time and leafhoppers collected were aspirated from the net, killed with benzene swabs and transferred to homeopathic vials, labelled and brought to the laboratory and dried in an oven at 40–45 °C for about 5–6 hours. The dried specimens were stored in small glass vials and labelled. For mounting and preparation of genitalia the procedure advocated

TABLE 1. Leafhopper species collected from different vegetable crops from different agro-climatic zones of Andhra Pradesh

Leafhopper	Host plants
1. *Austroagallia bifurcata*	Amaranthus, beans
2. *Batracomorphus angustatus*	Brinjal
3. *Balclutha incisa*	Broadbean, tomato, brinjal, mesta, spinach, ridgegourd, clusterbean, bittergourd, cucumber
4. *Balclutha pararubrostriata*	Tomato, bittergourd
5. *Balclutha saltuella*	Broadbean, cauliflower, tomato, ridgegourd, bittergourd, cucumber, okra, brinjal
6. *Cicadulina (Cicadulina) bipunctata*	Broadbean, amaranthus, mesta, spinach
7. *Deltocephalus (Deltocephalus) vulgaris*	Spinach
8. *Deltocephalus (Recilia) tareni*	Broadbean
9. *Exitianus indicus*	Chillies, spinach, amaranthus, ridgegourd, brinjal, cucumber
10. *Amrasca biguttula biguttula*	Brinjal, okra, radish, tomato, ridgegourd, mesta, spinach, clusterbean, frenchbean, gardenbean, cauliflower, chillies, beans
11. *Empoasca (Empoasca) motti*	Cowpea, mesta, coccinia, brinjal, frenchbean, broadbean, chillies, radish, amaranthus, spinach, ridgegourd, clusterbean, bittergourd, okra
12. *Empoasca punjabensis punjabensis*	Bittergourd, cucumber, snakegourd, coccinia, ridgegourd
13. *Empoasca (Distantasca) terminalis*	Beans
14. *Empoascanara defecta*	Spinach
15. *Seriana jaina*	Amaranthus, spinach, tomato, coriander, mesta, ridgegourd
16. *Hecalus porrectus*	Cucumber, brinjal
17. *Hishimonus phycitis*	Brinjal, ridgegourd, clusterbean
Vector species:	
Hishimonus phycitis	Vector of little leaf mycoplasma of brinjal

by Knight (1965) was followed. The terminology used in the present studies for the male genitalia and the other parts of leafhoppers are illustrated in Plate 2.

RESULTS AND DISCUSSION

In the present studies seventeen leafhoppers were identified from different vegetable crops grown in different agroclimatic zones of Andhra Pradesh in India (Plate 1 and Table 1) and the key is prepared to aid rapid and accurate identification of the common species. The key is based on male specimens only since the male genitalia usually provide the reliable diagnostic characters in leafhoppers.

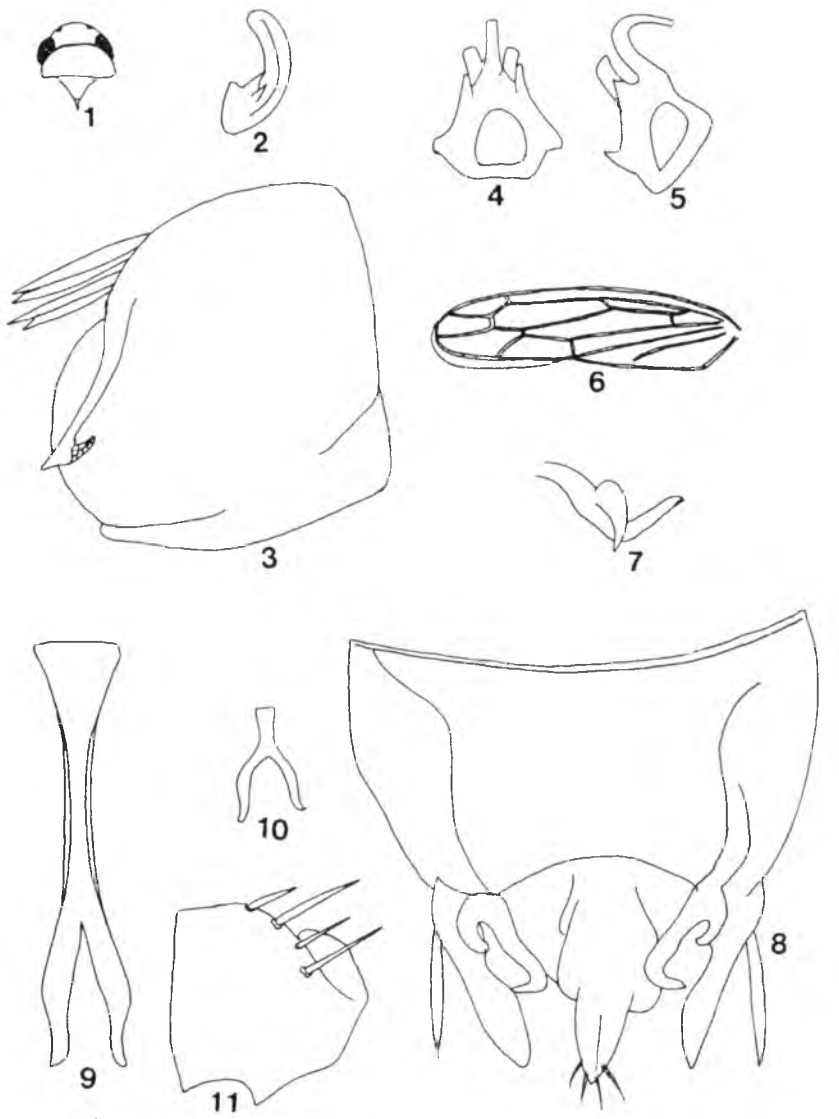

Fig. 1–3. *Cicadulina (Cicadulina) bipunctate*: 1. Head and Thorax; 2. Aedeagus lateral view; 3. Pygofer lateral view.
Fig. 4–5. *Balclutha incisa*: 4. Aedeagus dorsal view; 5. Aedeagus lateral view; 6. Forewing.
Fig. 7–9. *Balclutha pararubrostriata*: 7. Pygofer processes; 7. Pygofer dorsal view; 9. Connective.
Fig. 10–11. *Balclutha saltuella*: 10. Connective; 11. Pygofer lateral view.

Key to the leafhoppers of vegetable crops

1. Forewing with anteapical cells (Figs 6 and 25) 2
   Forewing without anteapical cells (Fig. 34) 12

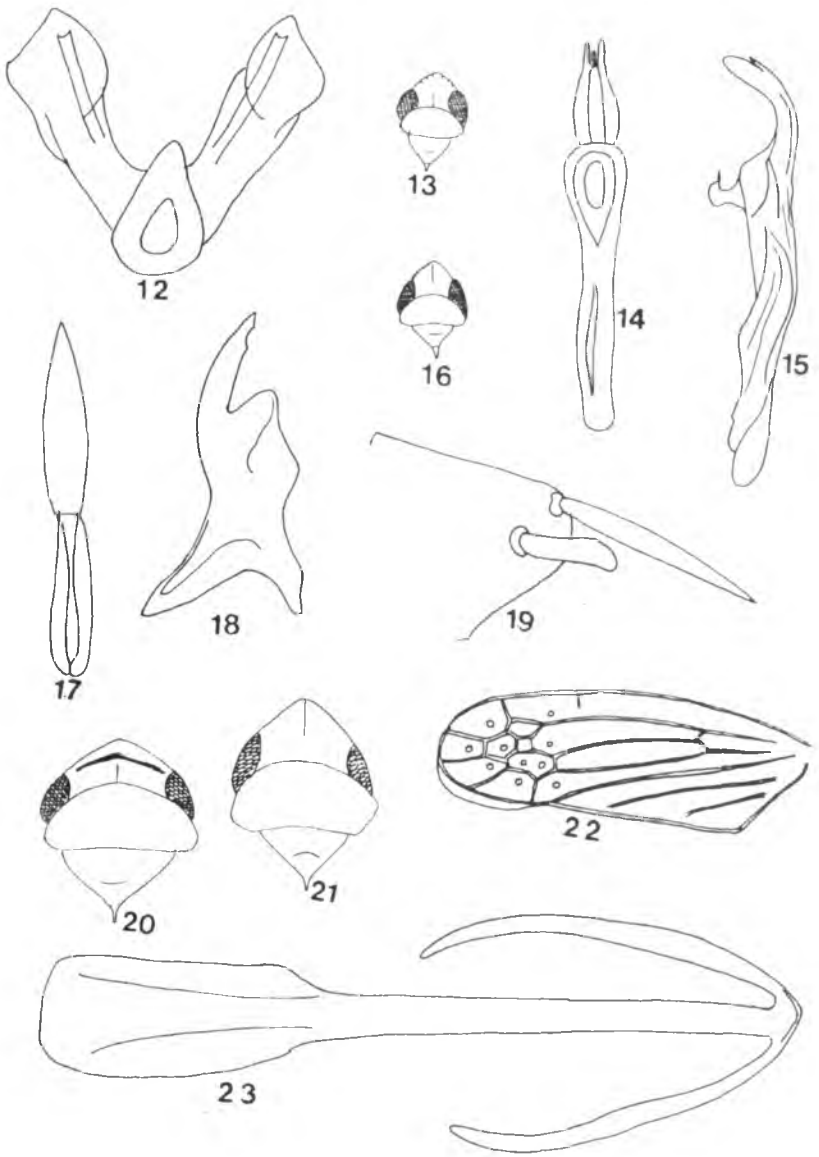

Fig. 12. *Hishimonus phycitis*, Aedeagus posterodorsal view.
Fig. 13–15. *Deltocephalus* (Deltocephalus) VOLGARIS. 13. Head and Thorax; 14. Aedeagus and connective dorsal view; 15. Aedeagus and connective lateral view.
Fig. 16–18. *D. (Recilla) tareni*: 16. Head and Thorax; 17. Aedeagus and connective dorsal view; 18. Style.
Fig. 19–20. *Exitianus indicus*: 19. Pygofer lobe lateral view; 20. Head and Thorax.
Fig. 21–23. *Hecalus porrectus*: 21. Head and Thorax; 22. Forewing; 23. Aedeagus dorsal view.

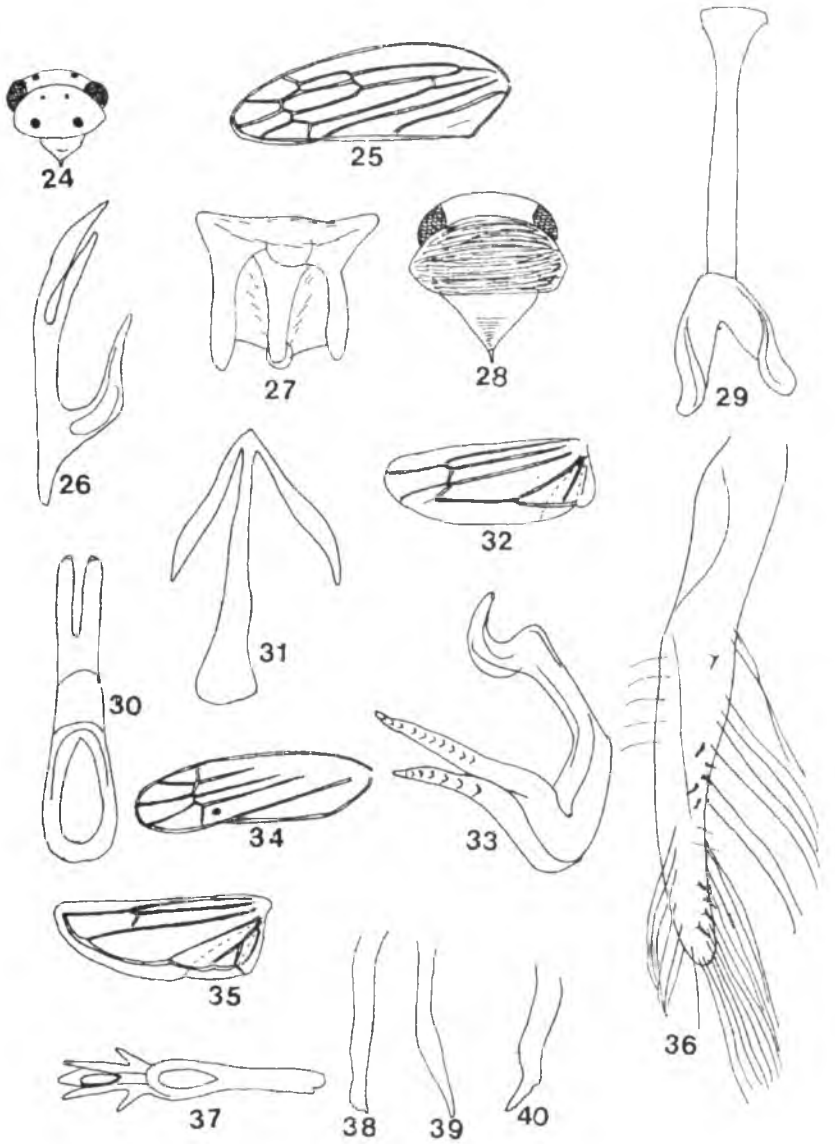

Fig. 24–27. *Austroagallia bifurcata* 24. Head and Thorax; 25. Forewing; 26. Aedeagus lateral view; 27. Aedeagus dorsal view.
Fig. 28–30. *Batracomorphys angustatus*: 28. Head and Thorax; 29. Connective; 30. Aedeagus dorsal view.
Fig. 31–32. *Seriana jaina*: 31. Aedeagus dorsal view; 32. Hindwing.
Fig. 33. *Empoascanara defecta*: Aedeagus lateral view.
Fig. 34–36. *A. biguttula biguttula*: 34. Forewing, 35. Hindwing, 36. Subgenital plate.
Fig. 37. *Empoasca (Disantasca) terminalis*: Aedeagus lateral view.
Fig. 38 & 39. Pygofer – Appendages in different orientations.
Fig. 40. *Empoasca (Empoasca) motti*: Pygofer – Appendages.

2. Forewing with two anteapical cells (Fig. 6) 3
Forewing with three anteapical cells (Fig. 25) 6

3. Vertex with a pair of round black spots on the anterior margin; pygofer with an elongate dorsal process with curved subapical spine; aedeagal shaft cylindrical, curved dorsally and C-shaped (Figs 1, 2 and 3)..... *Cicadulina (Cicadulina) bipunctata* (Melichar)
Vertex without any black spots or markings; pygofer process and aedeagus not as above 4

4. Aedeagus with three pairs of basal processes or projections (Figs 4 and 5)..... *Balclutha incisa* (Matsumura)
Aedeagus without such process 5

5. Pygofer processes bifurcated, branches hooked, dorsal one directed ventrad and ventral one directed dorsocaudad; connective arms shorter than its stem (Figs 7, 8 and 9) ..... *Balclutha pararubrostriata* Ramasubbarao and Ramakrishnan.
Pygofer without such processes; connective arms approximately as long as stem (Figs 10 and 11) ..... *Balclutha saltuella* (Kirschbaum)

6. Aedeagus with two broad shafts; forewing maculate with a discal semicircular spot (Fig. 12) ..... *Hishimonus phycitis* (Distant)
Aedeagus with a single shaft 7

7. Aedeagus fused with the connective (Figs 14 and 15) 8
Aedeagus not fused with the connective 9

8. Vertex with three pairs of very small (same diameter as ocelli) distinct spots on its anterior margin; aedeagus bifid apically with a spine like process in the middle ventrally; style not bidentate (Figs 13, 14 and 15)..... *Deltocephalus (Deltocephalus) vulgaris* Dash and Viraktamath.
Vertex without such spots; aedeagus not bifid apically; style bidentate (Figs 16, 17 and 18)..... *Deltocephalus (Recilia) tareni* Dash and Viraktamath

9. Pygofer lobe with two brown or black spines, spine-2 much thicker and shorter than spine-1; vertex with a black band between compound eyes (Figs 19 and 20) ..... *Exitianus indicus* (Distant)
Pygofer lobe heavily setose and without such specific black spines; vertex without such black band 10

10. Vertex subangularly acute to foliaceous with marginal ridge; aedeagus with terminal processes; forewing with apical one third brown in colour and with white spots in apical and anteapical cells (Figs 21, 22 and 23)..... *Hecalus porrectus* (Walker)
Vertex not acute or foliaceous, without any marginal ridge..... 11

11. Vertex with two pairs of conspicuous, black round spots, one pair on vertex and second pair on pronotum; aedeagus bifurcated with subequal branches; connective very short without clear distinction of stem and arms (Figs 24–27)..... *Austroagallia bifurcata* Sawai Singh and Gill
Vertex and pronotum without spots and rugose; aedeagal shaft clefted; connective

stem is very much longer than its arms and 'Y' shaped (Figs 28, 29 and 30) *Batracomorphus angustatus* (Osborn)

12. Vennal veins fused in the hindwing (Tribe: Erythroneurini) (Fig. 32) 13
    Vennal veins separate apically in hindwing (Tribe: Empoascini) (Fig. 35) 14
13. Aedeagal shaft with a pair of leaflike symmetrical processes (Fig. 31) .. *Seriana jaina* (Distant)
    Aedeagal shaft arcuated in side view without any processes; manubrial appendages longer and convergent apically with distinct transverse ledges in terminal half (Fig. 33) ..... *Empoascanara defecta* Dworakowska
14. Subgenital plates slender, elongate with numerous hairlike setae; vertex with two small black spots; forewings with a black spot in the apical half (Fig. 34, 35 and 36) ..... *Amrasca biguttula biguttula* (Ishida)
    Subgenital plates comparatively shorter and broader with hair like setae; vertex and forewings without such black spots 15
15. Aedeagal shaft with two pairs of processes (Fig. 37) ... *Empoasca (Distantasca) terminalis* Distant
    Aedeagal shaft without such processess 16
16. Lower pygofer appendage simple, tapering, slightly sinuated and outer surface serrated (Fig. 40) ..... *Empoasca (Empoasca) motti* Pruthi
    Lower pygofer appendage flattened (spatulate type) prepically and pointed at apex (Figs 38 and 39) ..... *Empoasca punjabensis punjabensis* Pruthi.

Ahmed Manzoor (1987) studied 33 Typhlocybine leafhoppers, their host associations and losses to growth and yield on some vegetable crops in Pakistan. Butani and Jotwani (1984) have given nature of feeding injury and control measures of nine leafhoppers on vegetables like brinjal, okra, tomato, peas etc. Singh *et al.* (1993) studied the leafhopper fauna of economic importance and their natural enemies in Karnataka state. But these works have not provided the keys for distinguishing these leafhoppers. In the present investigation, 17 leafhoppers are identified on different vegetable crops like brinjal, okra, tomato, amaranthus, spinach, cabbage, cauliflower, coccinia, cowpea, gourds etc and a key is provided along with illustrations for easy identification and for the use of Entomologists working in vegetable crops.

Among the vegetable leafhoppers, *A. biguttula biguttula* on brinjal and okra, *E. (Empoasca) motti* on clusterbean and coccinia and *H. phycitis* on brinjal have been observed in large numbers, feeding on the plants by sucking the sap and causing damage more than 10 per cent. Hence, they are said to have attained pest status. All others are considered as minor pests and some may attain pest status in due course of time, hence, the accurate identification of fauna associated with a particular agroecosystem is essential which may or may not attain pest status at present.

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REFERENCES

Ahmed Manzoor, (1987) Host associations and losses to growth and yield to some vegetable plants caused by Typhlocybine leafhoppers (Cicadellidae) in Pakistan, *Proceedings of 2nd International Work Shop on Leafhoppers and Planthoppers of Economic Importance held at Prove, Utah, USA, 28th July–1st August, 1986*, Wilson, M. R. and Nault, L. R.: (Editors). CIE: London, 243–250.

Butani, D. K. and Jotwani, M. G. (1984) *Insects in Vegetables*, Periodical Expert Book Agency, Vivek Vihar: Delhi 32, 356 pp.

Knight, W. J. (1965) Techniques fo use in the identification of leafhoppers (Homoptera: Cicadellidae), *Entomologist's Gazette* **16**: 129–136.

Singh, S. P., Rao, N. S. and Henneberry, T. J. (1993) *Leafhoppers and Their Natural Enemies*, Project Directorate of Biological Control: Banglore, 65 pp.

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Species Specific Anopheline Breeding Habitats with Reference to Malaria Control in Arsikere Taluk, Hassan District, Karnataka

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ABSTRACT: Species specific anopheline breeding habitats were studied from February 1996 to January 1997 in 50 villages of Arsikere Taluk, district Hassan, Karnataka with an aim to control malaria. Twelve species from wells, ten from bundh areas, nine each from streams and irrigation tanks, eight from stone quarries, seven from borrow pits, three each from pipe leakage water collections, cemented pots and paddy fields and two from irrigation channels had emerged. Wells, irrigation tanks and streams were the major whereas the remaining ones were minor breeding habitats for malaria vectors namely *Anopheles culicifacies*, Giles and *An. fluviatilis*, James. Significant positive correlation of *An. culicifacies* with *An. annularis*, Van der Walp in tanks and *An. varuna*, Iyengar in wells was observed ($P < 0.001$). Significant *An. culicifacies* contribution was observed in combinations between tanks, wells, stone quarries, bundh areas and borrow pits ($P < 0.05$). Mosquito breeding control in these habitats through bioenvironmental methods has been highlighted.

KEYWORDS: Anophelines, breeding, habitat, Arsikere Taluk.

INTRODUCTION

Malaria was showing rising trend in the rural areas of Arsikere Taluk, district Hassan, Karnataka (NAMP, 1996). Control measures adopted in this area were residual indoor

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spraying with DDT. This conventional approach to interrupt malaria transmission is associated with many problems like development of insecticide resistance to vector mosquitoes, drug resistance to parasites, exophilic and/or exophagic behaviour of vectors, environmental contamination and high cost of insecticides. Hence it was envisaged to control malaria through alternate strategies and bioenvironmental control is one such strategy which is under implementation in the country (Sharma, 1993). For successful implementation of this approach, it is essential to identify the breeding habitats of anophelines specially the vectors in the area (Yadav *et al*, 1989). *Anopheles culicifacies*, Giles and *An. fluviatilis*, James are the main rural vectors of malaria in Karnataka (Rao, 1948). Most of the studies regarding ecology of anophelines in Hassan district were conducted in early to mid part of the last century (Rao *et al*, 1952; Brook Worth, 1953; Bhombore *et al*, 1954). During the last four decades there have been vast ecological changes in this area. Hence an attempt was made to study species specific anopheline breeding habitats with particular emphasis on malaria vectors in order to implement bioenvironmental approach for malaria control in Arsikere Taluk of district Hassan, Karnataka.

MATERIAL AND METHODS

Arsikere Taluk of district Hassan comprises of 503 villages. Anopheline immatures were collected from all possible breeding habitats belonging to 50 villages of Arsikere Taluk from February 1996 to January 1997. Spot surveys were carried out from irrigation tanks (116 samples), wells (396), streams (51), stone quarries (39), bundh areas (52), borrow pits (42), pipe leakage water collections (5), cemented pots (5), irrigation channels (3) and paddy fields (3). The anopheline immatures were collected using a dipper of 9.5 cm diameter (300 ml. capacity) and/or a bucket of 5 lt capacity using a glass pipette depending on the nature of the breeding habitats. The samples were brought to the laboratory and reared until adult emergence. All adult mosquitoes were identified under stereoscopic microscope using the key of Christophers (1933) and Das *et al* (1990).

Percent composition of different species was worked out among the total adults emerged from all samples of a particular habitat. Percent composition among total adults belonging to a particular species from different breeding habitats was also calculated. Correlation co-efficient test was applied to find out correlation between principal malaria vector species *viz.*, *An. culicifacies* and other common anopheline species in major breeding habitats. One-way ANOVA test was also applied for statistical significance of vector contribution from different habitats.

RESULTS AND DISCUSSION

A total of 3585 adults composed of thirteen anopheline species emerged from different mosquito breeding habitats *viz.*, irrigation tanks, wells, streams, stone quarries, bundh areas, borrow pits, pipe leakage water collections, cemented pots, irrigation channels and paddy fields. Table 1 represents the percent composition of anopheline species

in different breeding habitats. The total number of species emerged from a particular habitat revealed that maximum twelve species emerged from wells followed by ten from bundh areas, nine each from streams and irrigation tanks, eight from stone quarries, seven from borrow pits, three each from pipe leakage water collections, cemented pots and paddy fields and two from irrigation channels.

An. culicifacies breeding was observed to be ubiquitous in all types of breeding habitats which is in accordance with the earlier findings (Rao, 1984). Percent composition of *An. culicifacies* in the total adults emerged from stone quarries, irrigation channels, pipe leakage water collections, streams, wells, irrigation tanks, bundh areas, borrow pits and paddy fields was 46.33, 40.00, 35.29, 31.49, 30.94, 27.12, 20.54, 15.91 and 9.09 respectively. Bhombore *et al* (1954) reported the breeding of *An. culicifacies* usually in slow moving fresh water and pools in sandy river beds in western hill tracts of Mysore state. Present study revealed that percent composition of *An. culicifacies* in streams was 31.49. *An. culicifacies* breeding has not been recorded in man made cemented cisterns (Rao, 1984). However, in the present investigation composition of *An. culicifacies* from cemented pots was 38.89%. It indicates that some ecological compulsion of the species to breed in other habitats.

An. fluviatilis breeding was maximum observed in streams. Out of the total adults emerged in streams this species accounted for 4.53%. Rao *et al* (1952) and Puri (1949) also found the breeding of *An. fluviatilis* mainly in streams. In other breeding sites *viz.*, wells, borrow pits, bundh areas and irrigation tanks, the percent composition of *An. fluviatilis* was 1.97, 0.38, 0.34 and 0.10 respectively. *An. varuna*, Iyengar was found to breed in wells and water pools such as stone quarries and bundh areas. Its percent composition in total adults emerged from these breeding sites was 1.55, 0.57 and 0.34 respectively. This confirms the earlier findings in this area (Puri, 1949; Iyengar, 1924). However, Rao *et al* (1952) noticed its breeding usually in streams in Hassan district.

An. annularis, Van der Wulp breeding was mainly recorded from irrigation tanks, bundh areas and stone quarries. Its percent composition from these habitats was 33.82, 31.98 and 20.34 respectively. Yadav *et al* (1989) reported the composition of *An. annularis* out of total adults emerged from wells was 1.50%. However, in present study the percent composition of *An. annularis* in wells was 5.27.

Prolific breeding of *An. subpictus*, Grassi was observed in all types of habitats searched. Its composition in total adults emerged from irrigation tanks, wells, streams, stone quarries, bundh areas, borrow pits, pipe leakage water collections, cemented pots, irrigation channels and paddy fields was 31.31, 49.51, 46.35, 15.25, 37.37, 71.21, 52.94, 44.44, 60.00, and 72.72% respectively.

An. vagus, Donitz was found to breed almost in all kind of breeding habitats checked. Its breeding was mainly recorded from paddy fields, cemented pots, stone quarries and pipe leakage water collections. Percent composition of this species from other breeding sites such as streams, wells, bundh areas, irrigation tanks and borrow pits was 4.79, 4.43, 4.38, 3.46 and 0.76 respectively.

An. pallidus, Theobald preferred to breed in bundh areas (2.35%) followed by stone quarries (1.69%), irrigation tanks (0.84%) and streams (0.25%).

TABLE 1. Percent composition of anophelines in different breeding habitats in rural area of Arsikere Taluk, Hassan District, Karnataka

Breeding Habitat	An. cul.	An. flu.	An. aco.	An. var.	An. ann.	An. pal.	An. sub	An. vag.	An. bar.	An. hyr.	An. pseudo jam.	An. tes.	An. theo.
Irrigation tank	27.12	0.10	—	—	33.82	0.84	3.131	3.46	1.15	1.89	0.30	—	—
116	(259)	(1)			(323)	(8)	(299)	(33)	(11)	(18)	(3)		
Well	30.94	1.97	0.14	1.55	5.27	—	49.51	4.43	5.35	0.42	0.07	0.14	0.21
396	(440)	(28)	(2)	(22)	(75)		(704)	(63)	(76)	(6)	(1)	(2)	(3)
Stream	31.49	4.53	—	—	5.54	0.25	46.35	4.79	5.54	1.26	0.25	—	—
51	(125)	(18)			(22)	(1)	(184)	(19)	(22)	(5)	(1)		
Stone quarray	46.33	—	—	0.57	20.34	1.69	15.25	12.99	0.57	2.26	—	—	—
39	(82)			(1)	(36)	(3)	(27)	(23)	(1)	(4)			
Bundh areas	20.54	0.34	—	0.34	31.98	2.35	37.37	4.38	1.01	1.35	—	—	0.34
52	(61)	(1)		(1)	(95)	(7)	(111)	(13)	(3)	(4)			(1)
Borrow pit	15.91	0.38	—	—	8.71	—	71.21	0.76	2.65	0.38	—	—	—
42	(42)	(1)			(23)		(188)	(2)	(7)	(1)			
Pipe leakage	35.29	—	—	—	—	—	52.94	11.77	—	—	—	—	—
5	(12)						(18)	(4)					
Cemented pot	38.89	—	—	—	—	—	44.44	16.67	—	—	—	—	—
5	(7)						(8)	(3)					
Irrigation channel	40.00	—	—	—	—	—	60.00	—	—	—	—	—	—
3	(4)						(6)						
Paddy field	9.09	—	—	—	—	—	72.72	18.19	—	—	—	—	—
3	(1)						(8)	(2)					

Figures in parentheses indicate number of mosquitoes emerged. Figures below breeding sites are number of samplings. An. cul. - *An. culicifacies*, An. flu. - *An. fluviatillis*, An. aco. - *An. aconitus*, An. var. - *An. varuna*, An. ann. - *An. annularis*, An. pal - *An. pallidus*, An. sub. - *An. subpictus*, An. vag. - *An. vagus*, An. bar. - *An. barbirostris*, An. hyr. - *An. hyrcanus* group, An. pseudojam - *An. pseudojamesi*, An. tes. - *An. tessellates*, An. theo. - *An. theobaldi*.

TABLE 2. Coefficient of correlation between *An. culicifacies* and other common anopheline species in major breeding habitats

Breeding Habitat	An. flu.	An. var.	An. ann.	An. pal.	An. sub.	An. vag.	An. bar.
Irrigation tank			+0.71*		−0.53	−0.21	
			±0.22		±0.27	±0.31	
Well	+0.39	+0.73*	+0.51		−0.36	+0.13	−0.22
	±0.29	±0.22	±0.27		±0.29	±0.31	±0.31
Stream	+0.11		+0.03		−0.15	+0.10	+0.12
	±0.31		±0.32		±0.31	±0.31	±0.31
Stone quarray			+0.32		−0.43	+0.03	
			±0.30		±0.28	±0.32	
Bundh area	+0.06	−0.06	+0.48	+0.18			
			±0.31	±0.31	±0.28	±0.31	
Borrow pit	+0.13		−0.29		+0.01		
			±0.31		±0.30		±0.32

*Significant ($P < 0.01$).
An. flu. - *An. fluviatillis*, An. var. - *An. varuna*, An. ann. - *An. annularis*, An. pal - *An. pallidus*, An. sub. - *An. subpictus*, An. vag. - *An. vagus*, An. bar. - *An. barbirostris*.

An. tessellatus, Theobald was found to breed only in wells. Its percent composition out of total adults emerged from wells was only 0.14. Bhombore *et al* (1954) reported that larvae of this species require small pools for breeding.

An. barbirostris, Van der Wulp showed breeding preference for wells and streams and *An. hyrcanus*, group Pallas for stone quarries, irrigation tanks, bundh areas and streams though their breeding was recorded in all major breeding habitats searched. However, earlier reports indicate abundance of these species mainly due to extensive paddy fields (Bhombore *et al*, 1954). Among other species *An. pseudojamesi*, Strickland and Chowdhury was found to breed in irrigation tanks, streams and wells, *An. theobaldi*, Giles in bundh areas and wells and *An. aconitus*, Donitz only in wells.

Coefficient of correlation between *An. culicifacies* and other common anopheline species in major breeding habitats showed significantly ($P < 0.01$) positive correlation with *An. annularis* in tanks and *An. varuna* in wells. Other species showed partial repulsion (Table 2).

Habitat wise anopheline species composition is given in Table 3. Wells supported primarily the breeding of *An. culicifacies* (42.59%), *An. fluviatilis* (57.14%), *An. aconitus* (100.00%), *An. subpictus* (45.33%), *An. vagus* (38.89%), *An. tessellatus* (100.00%), *An. theobaldi* (75.00%) *An. barbirostris* (63.33%) whereas, the breeding of *An. hyrcanus* group (15.79%), *An. pseudojamesi*, (20.00%) and *An. annularis* (13.07%) was secondary and tertiary respectively. Wells have not been reported to be the usual breeding habitat for *An. varuna* in Hassan district (Rao *et al*, 1952). However, in the present investigation *An. varuna* breeding was mainly found in wells. This substantiates the earlier findings of Puri (1949). Irrigation tanks contributed the

maximum breeding of *An. annularis* (56.27%), *An. pallidus* (42.11%), *An. hyrcanus* group (47.37%) and *An. pseudojamesi* (60.00%). However, percent compositions of other mosquitoes like *An. culicifacies, An. fluviatilis, An. subpictus, An. vagus, and An. barbirostris* were 25.07, 2.04, 19.25, 20.37 and 9.17 respectively. Stream was found to be second most abundant breeding site for *An. fluviatilis* (36.74%) and third most for *An. culicifacies* (12.10%). The percent composition of other species *viz., An. annularis, An. pallidus, An. subpictus, An. vagus, An. barbirostris, An. hyrcanus* group and *An. pseudojamesi* was 3.83, 5.26, 11.85, 11.73, 18.33, 13.15 and 20.00 respectively. Stone quarries were mostly responsible for *An. pallidus* (15.79%), *An. vagus* (14.20%), *An. hyrcanus* group (10.53%), *An. culicifacies* (7.94%), *An. annularis* (6.27%) and *An. varuna* (4.17%) in the area examined. The main breeding from bundh areas in the present investigation was *An pallidus* (36.84%) followed by *An. theobaldi* (25.00%), *An. annularis* (16.55%), *An. hyrcanus* group. (10.53%), *An. vagus* (8.03%), *An. subpictus* (7.15%), *An. culicifacies* (5.90%) and *An. varuna* (4.17%). Borrow pits supported 12.11% *An. subpictus*, 5.84% *An. barbirostris*, 4.07% *An. culicifacies*, 4.01% *An. annularis*, 2.63% *An. hyrcanus* group and 2.04% *An. fluviatilis*. Other breeding habitats such as pipe leakage water collections, cemented pots, irrigation channels and paddy fields mainly shared by *An. subpictus* and *An. vagus* in the area studied.

ANOVA test did not reveal any significant difference for *An. culicifacies* contribution between tank and well, stream and stone quarry, stream and bundh area, stone quarry and bundh area, borrow pit and stone quarry and borrow pit and bundh area. However, other breeding habitat combinations showed significant ($P < 0.05$) difference in the area (Table 4).

An. culicifacies has been reported to be the malaria vector in maidan area of Hassan district, Karnataka (Rao, 1948). Present study revealed that wells and irrigation tanks are the main breeding habitats for this species. Further, *An. fluviatilis* and *An. varuna* known malaria vectors were also found to breed extensively in these breeding habitats. Mosquito breeding in these habitats can be effectively controlled by introduction of larvivorous fish *viz.*, 'Top Minnow, (*Gambusia affinis,* Baird & Girard) or Guppy (*Lebistes reticulatus*, Peters) after proper margining and deweeding. Larvivorous fishes have been utilised successfully for mosquito breeding control in wells, cisterns and ornamental ponds in Karnataka (Rao, 1971). Introduction of larvivorous fish can also control the breeding of mosquitoes in stone quarries, bundh areas, borrow pits and cemented tanks (Sharma, 1993). Besides fish introduction, expanded polystyrene (EPS) beads can be used for mosquito breeding control in unused wells (Sharma *et al*, 1985). Biocide, intermittent irrigation, minor engineering works (Rao, 1948; Sharma, 1993) and flushing (MacDonald, 1939; Worth, 1940) can also be tried for the control of mosquito breeding in paddy fields, irrigation channels and streams. Pipe leakage problem can be tackled simply by repairing of pipe by water works department through inter-departmental co-ordination.

TABLE 3. Percent composition among total adults belonging to a particular species from different breeding habitats in rural area of Arsikere Taluk, District Hassan, Karnataka

Breeding Habitat	An. cul.	An. flu.	An. aco.	An. var.	An. ann.	An. pal.	An. sub.	An. vag.	An. bar.	An. hyr.	An. pseudo jam.	An. tes.	An. the.	Total
Irrigation tank	25.07	2.04	—	—	56.27	42.11	19.25	20.37	9.17	47.37	60.00	—	—	26.64
Well	42.59	57.14	100.00	91.66	13.07	—	45.33	38.89	63.33	15.79	20.00	100.00	75.00	39.67
Stream	12.10	36.74	—	—	3.83	5.26	11.85	11.73	18.33	13.15	20.00	—	—	11.07
Stone quarry	7.94	—	—	5.17	6.27	15.29	1.74	14.2	0.83	10.53	—	—	—	4.94
Bundh areas	5.90	2.04	—	4.17	6.27	15.79	1.74	14.2	0.83	10.53	—	—	25.00	8.28
Borrow pit	4.07	2.04	—	—	4.01	—	12.11	1.23	5.84	2.63	—	—	—	7.36
Pipe leakage	1.16	—	—	—	—	—	1.16	2.47	—	—	—	—	—	0.95
Cemented pot	0.68	—	—	—	—	—	0.51	1.85	—	—	—	—	—	0.5
Irrigation channel	0.39	—	—	—	—	—	0.39	—	—	—	—	—	—	0.28
Paddy field	0.10	—	—	—	—	—	0.51	1.23	—	—	—	—	—	0.31

An. cul. - *An. culicifacies*, An. flu. - *An. fluviatillis*, An. aco. - *An. aconitus*, An. var. - *An. varuna*, An. ann. - *An. annularis*, An. pal - *An. pallidus*, An. sub. - *An. subpictus*, An. vag. - *An. vagus*, An. bar. - *An. barbirostris*, An. hyr. - *An. hyrcanus* group, An. pseudojam - *An. pseudojamesi*, An. tes. - *An. tessellates*, An. theo. - *An. theobaldi*.

TABLE 4. ANOVA 'F' values for *An. culicifacies* in different major breeding habitats

Breeding Habitat	Irrigation tank	Well	Stream	Stone quarry	Bundh area
Well	3.7				
	$P > 0.05$				
Stream	5.77	11.98			
	$P < 0.05$	$P < 0.05$			
Stone quarry	12.36	16.64	1.08		
	$P < 0.05$	$P < 0.05$	$P > 0.05$		
Bundh area	17.85	19.50	2.98	0.55	
	$P < 0.05$	$P < 0.05$	$P > 0.05$	$P > 0.05$	
Borrow pit	21.12	21.40	4.90	1.93	0.73
	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P > 0.05$	$P > 0.05$

Thus this study is of immense importance for planning anti-larval operations under selective vector control programme for malaria specially through bioenvironmental control approach.

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REFERENCES

Bhombore, S. R., Sitaraman, N. L. and Brook Worth, C. (1954) Seasonal prevalence of Anophelines in western hill tracts of Mysore state, *Indian J. Malariol.* **8**: 47–62.

Brook Worth, C. (1953) Notes on the Anopheline fauna of hill tract in Mysore State India, *Indian J. Malariol.* **7**: 125–182.

Christophers, S. R. (1933) *The Fauna of British India Including Ceylon and Burma*, Vol. 4. Today and Tomorrow's printers and publisher: New Delhi, 1–359.

Das, B., Rajagopal and Akiyama (1990) Pictorial key to Indian Anopheline mosquitoes, *J. Pure Appl. Zool.* **2**: 133–159.

Iyengar, M. O. T. (1924) On the Indian Anophelines of the funestus group and the description of new species (Diptera: Culicidae), *Ind. J. Med. Res.* **12**: 23–29.

MacDonald, G. (1939) A design of flushing siphon for control of Anopheline breeding, *J. Mal. Inst. Ind.* **2**: 63–69.

National Anti Malaria Programme (NAMP) Bangalore, Annual Report, 1996.

Puri, I. M. (1949) *Synoptic Tables for the Identification of the Full Grown Larvae of the Indian Anopheline Mosquitoes*, 6th edition, Health Bulletin No. 16, Malaria Bureau No. 7. Manager of Publication: Delhi.

Rao, B. A. (1948) A short account of the malaria problem in Mysore State, *Ind. J. Malariol.* **2**: 285–305.

Rao, B. A., Rama Rao, T. S. and Sitaraman, N. L. (1952) Anopheline mosquitoes recorded in the districts of Shimoga and Hassan, Mysore State, *Indian J. Malariol.* **6**: 475–480.

Rao, B. A. (1971) Use of fishes in the control of mosquito breeding in Mysore State. In Malaria Eradication in Mysore State, Desai, P. R. and Srivastava, H. M. L.: (Editors). Directorate of Health and Family planning, Government of Mysore: Bangalore, 57–58.

Rao, T. Ramachandra (1984) *The Anophelines of India*, Revised edition. Malaria Research Centre, I.C.M.R.: Delhi.

Sharma, R. C., Yadav, R. S. and Sharma, V. P. (1985) Field application of expanded polystyrene (EPS) beads in mosquito control, *Ind. J. Malariol.* **22**: 107–109.

Sharma, V. P. (1993) *Malaria Control: Bioenvironmental Method and Community Participation. In Community Participation in Malaria Control*, Sharma, V. P.: (Editor). Akshdeep Printers: New Delhi, 1–42.

Worth, H. N. (1940) Antilarval flushing of rivers and streams in Ceylon, *J. Mal. Inst. Ind.* **3**: 81–92.

Yadav, R. S., Sharma, R. C., Bhatt, R. M. and Sharma, V. P. (1989) Studies on the Anopheline fauna of Kheda district and species specific breeding habitats, *Indian J. Malariol.* **26**: 65–74.

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Suitability of Substrata for the Mass Rearing of *Rhynocoris fuscipes* (Heteroptera: Reduviidae), a Key Predator of Pod Borer *Helicoverpa armigera* (Hubn.)

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ABSTRACT: Stadial periods of nymphal instars of *Rhynocoris fuscipes* (Fabricius) reared on dry plant litter and green plant shoot were greatly shortened compared to that on tissue and glutting papers, plastic substrate and sand with stone substrata. Predator survival was better on green plant shoot than on such other sunstrata plastic, sand with stone, tissue and glutting papers and dry litter with strip. Previpopsition period was shortened on the green plant shoot and tissue and glutting paper substrata. Fresh adult body weights were slightly higher when *R. fuscipes* was reared on four varied substrata than those reared on untreated plastics substrata. Fecundity was significantly higher on green plant shoot substrate category.

KEYWORDS: Suitabile substrata, *Rhynocoris fuscipes*, mass rearing, biocontrol agent.

INTRODUCTION

The predaceous insects particularly reduviid bugs are the promising species for use in biological control of lepidopteran insect pests including *Helicoverpa armigera* (Hubn.) and may be an important alternative to chemicals (Whitcomb, 1994; Sahayaraj, 1995; Duffield and Reddy, 1997; Ambrose, 1999). Little effort has been made to conserve the reduviids of key pests such as *Rhynocoris, Sycanus, Ectomocoris, Irantha*. Though, grouping of this gregarious species might extent positive influence upon survival, development and morpho-functional characters (Inoue, 1985; Ambrose and Claver, 1997), more information on the influence of substrata on mass-rearing on this predator is needed to understand better its efficient mass-multiplication strategies. Though it is a known fact that substrata could influence multiplication of the predator population, information on the role of substrata on the life cycle, on laboratory rearing

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of predator on different substrata, and on predator's substrata preference is scanty. Keeping in view of the above facts, an attempt was made to study the effects of varied substrata on the development of *R. fuscipes*. Such information would enable us to select the most acceptable rearing substratum for reduviid multiplication in the laboratory. The present study compares the influence of five rearing substrata viz., tissue and glutting papers, sand and stone, dry plant litter and green plant shoot on the stadial period, nymphal survival, adult weight, sex ratio and fecundity of *R. fuscipes* during mass rearing.

MATERIALS AND METHODS

A laboratory colony of *R. fuscipes* was established from nymphs and adults collected from the pigeonpea agro-ecoregion, 28 km away from Palayankottai. *R. fuscipes* was maintained at 28 ± 2 °C, 68 ± 5% Rh and a 13 : 11 (L : D) photoperiod, individually. Twenty five newly laid eggs were placed in group in 15 cm diameter plastic boxes. Nymphs were transferred to 21 × 16 cm plastic boxes upon reaching the second instars. To prevent reduviid escape, each rearing box was covered with a tight fitting lid possessed with plastic mesh. Throughout their development adults and nymphs of *R. fuscipes* received a constant daily supply of larvae of *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae). Prey colonies were maintained at 25 ± 2 °C humidity with 72 ± 3 Rh and a photoperiod of 13 : 11 (L : D) using the method proposed by Kalyanasundaram (1992). The following substrata types were tested.

1. Untreated plastic box.
2. Tissue and chart papers (tissue paper was laid on the box floor and a bit of multi folded chart paper was placed on the tissue paper for the reduviids to hide).
3. Dry sand and stone (sand was spread uniformly in the box up to 2 cm height and stones (approx. 5 × 3 cm size) were placed on it; care was taken to keeping the concave side of the stone facing the earth to facilitate the hiding of reduviids).
4. Dry plant litter (litter strips of plant leaves and twigs were filled in the box up to 4 cm height and some small strips were placed over it for easy movement of reduviids).
5. Green plant shoot (fresh pigeonpea shoot with leaves was placed inside the box and adequately replaced at regular interval at least once in 4 days to keep the leaves fresh).

The boxes were observed daily to record, moulting and instar duration. Biological attributes such as incubation, stadial and preoviposition periods, nymphal survival, sex ratio of emerging adults and fresh weight of neonate male and female were recorded in each category. We paired *R. fuscipes* males and females in 15 × 10 cm containers within 3 days of adult emergence and allowed them to mate. Four days later males were removed and mated females received their respective rearing substrate for oviposition. Total egg counts of five gravid females reared per substrate were recorded. These mass rearing experiments and observations were conducted on five different rearing

substrata in four replications during 1998–2000. Substrata impacts on oviposition were compared using student's 't' test.

RESULTS AND DISCUSSION

Though substrata did not influence the incubation period, the stadial periods of nymphal instars of *R. fuscipes* reared on dry plant litter with strip and green plant shoot were greatly shortened over three categories. DeBach and Hagen (1964); Watson (1964); Ali and Watson (1978); Braman *et al* (1984) and Whitcomb (1994) pointed out that developmental duration of predators prolonged when the abiotic factors varied. Moreover, Eigenbrode *et al* (1996) stated that the devlopmental period prolonged when tarsal sensilla of anthocorid *Orius insidius* (Say) were damaged or coated with debris while working on polished surface or wax layered plants.

Green plant shoot supported better survival than did other substrata. This difference was probably because of higher nymphal cannibalism at untreated plastic substrata and sand with stone substrata. Similarly Yadav *et al* (1998) reported that survival of chrysopid larval predators was more in bioassay substrata over iron sheet and plastic substrata. McPherson *et al* (1982) stated that fallen dead leaves could form conducive microhabitats for reduviids' high biological activity and survival. Moreover, King and Morrison (1984) stated that insect survival was dependent on the habitat suitability of substrata and also on their level of phenotypic and somatic plasticity.

Preoviposition period was shortened in the green plant shoot and tissue and glutting papers substrata. But it did not differ significantly among all other treatments. However, Drukker *et al* (1995) stated that plastic and its odour reduced the possibility of oviposition of an anthocorid *O. insidius*. This could be the reason for the extension of oviposition period in untreated plastic substrate. Moreover, Evans (1976) and Ferran *et al* (1996) stated that sensilla of rostrum receive physical (superficial texture) and/or chemical (local humidity, plant secretion, gas exchange) information from plants and this information would motivate female predatory bugs for oviposition, but lack of such plant substrates or a deficiency of qualitative or quantitative cues from the plant would delay or avoid oviposition.

The fresh adults body weights were slightly higher for *R. fuscipes* reared on four varied substrata than those reared on untreated plastic substrata. Decrease in adult body weight of *R. fuscipes* reared in plain plastic boxes could be attributed to the negative impact of plastic boxes (Drukker *et al*, 1995). Murdiels (1969) reported a 20% reduction in male weight and a 35% reduction in female weight of pea aphid due to rearing habitat stress. Evans (1982) further stressed that body weights is a major determinant of egg production in predatory stink bugs.

The sex ratio was a slightly female biased in all the tested mass-rearing conditions. Similar female biased sex ratio as a function of mass-rearing was reported for *Rhynocoris marginatus* Fabricius, *R. kumarii* Ambrose and Livingstone and *R. fuscipes* (Ambrose, 1999; Claver *et al*, 1996). Moreover, Long and Zaher (1958) reported that insect mass-rearing produced larger adults with a greater effect on females.

TABLE 1. Influence of five different substrata on some biological attributes of *Rhynocoris fuscipes* ($n = 23$, $\bar{x} \pm$ SE)

Biological attributes	Substrata				
	UP	TG	SS	DL	GS
Incubation period (days)	7.0 ± 0.87	7.0 ± 2.19	6.7 ± 1.82	7.5 ± 2.89	6.2 ± 0.94
Stadial period (days)	45.5 ± 4.53	43.7 ± 3.67	40.4 ± 5.63	39.8 ± 7.06	35.90 ± 6.2
Nymphal survival (%)	37.5 ± 8.90	56.4 ± 8.83	66.6 ± 12.3*	64.9 ± 10.71*	71.4 ± 10.5**
Sex ratio (male : female)	1 : 1.1	1 : 1.3	1 : 1.2	1 : 1.2	1 : 1.2
Adult weight (mg)	71.8 ± 5.95	73.9 ± 18.4	76.3 ± 7.74	71.2 ± 15.3	78.2 ± 10.64
Preoviposition period (days)	16.3 ± 4.67	15.9 ± 6.72	14.9 ± 3.45	14.4 ± 2.62	12.99 ± 2.45**
Fecundity (egg/female)	57.6 ± 9.66	79.9 ± 12.39*	84.0 ± 14.1*	92.1 ± 11.1*	108.1 ± 12.7**

UP = untreated plastic box; TG = tissue and glutting papers; SS = sand and stones; DL = dry plant litter; GS = green plant shoot. (* $P = 0.01$; ** $P = 0.005$).

Significantly the highest fecundity was found on the pigeonpea shoot substrate category. Gautam (1990a,b) also reported that predaceous coccinellid beetles preferred to deposit their eggs on the cotton and folded tissue paper rather than on other glass and plastic substrata. Moreover, Naranjo and Stimac (1987); Snodgrass and McWilliam (1992) and Ferran *et al* (1996) stated that oviposition non-preference appeared to be important for predatory bugs population in certain substrate, where adults colonize but do not reproduce well. Furthermore, Hedge and Patil (1995) and Karuppachamy *et al* (1998) reported that the multiplication of predator was faster in preferred green leaves provided on substrate. This might be an important reason for the higher fecundity registered on green leaves and stem substrate. The present findings suggest that mass-rearing of reduviid predators, such as *R. fuscipes* in plain plastic trough is not advisable and inclusion like green pigeonpea shoot as substrata could enhance its mass rearing potential.

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REFERENCES

Ali, A.-S. A. and Watson, T. F. (1978) Effects of temperature on development and survival of *Zelus renardii*, *Environ. Entomol.* 7: 889–890.

Ambrose, D. P. (1999) *Assassin Bugs*, Science Publishers, Inc. Enfield New Hampshire: USA, 337.

Ambrose, D. P. and Claver, M. A. (1997) Functional and numerical responses of the reduviid predator *Rhynocoris fuscipes* (F.) (Het.Reduviidae) to cotton leafworm *Spodoptera litura* (F.) (Lep., Noctuidae), *J. Appl. Entomol.* **121**: 331–336.

Braman, S. K., Solderbeck, P. E. and Yeargen, K. V. (1984) Effect of tempetature on the development and survival of *Nabis americoferus* and *N. roseipennis* (Hemiptera: Nabidae), *Ann. Entomol. Soc. Am.* **77**: 592–596.

Claver, M. A., Rajan, K. and Ambrose, D. P. (1996) Impact of mass rearing in the postembryonic development of *Rhynocoris kumarii* Ambrose and Livingstone (Heteroptera: Reduviidae), In: *Biological and Cultural Control of Insect Pests, an Indian Scenario*, Ambrose, D. P.: (Editor). Adeliine Publisher: Tirunelveli, India, 216–219.

DeBach, P. and Hagen, K. S. (1964) Manipulation of entomophagous species, In: *Biologival Control of Insect Pests and Weeds*, De Bach, P. and Schlinger, E. I.: (Editors). Chapman & Hall, L.A.: 429–458.

Duffield, S. J. and Reddy, Y. V. R. (1997) Distribution and movement of predators of *Helicoverpa armigera* in intercropped sorghum and short-duration pigeonpea, *Crop. Res.* **14(2)**: 315–335.

Drukker, B., Scutareanu, P. and Sabelis, M. V. (1995) Do anthocorid predators respond to sunomones from *Psylla*-infested pear trees under field conditions? *Entomol. Expl. Appl.* **77**: 193–203.

Eigenbrode, S. D., Castagnola, T., Roux, M. B. and Steljes, L. (1996) Mobility of three generalist predators is greater on cabbage with glossy leaf wax than on cabbage with a wax bloom, *Entomol. Expl. Appl.* **81**: 335–343.

Evans, E. W. (1976) The effect of prey density and host plant characteristics on oviposition and fecundity in *Anthocoris confusus* (Reuter), *Ecol. Entomol.* **1**: 157–161.

Evans, E. W. (1982) Timing of reproduction by predatory stinkbugs (Heteroptera: Pentatomidae), patterns and consequences for a generalist and a specialist, *Ecology* **63**: 147–158.

Ferran, A., Rortail, A., Malansa, J. C. and Gambier, J. (1996) Ovipositional behaviour of *Macrolophus caliginous* (Heteroptera: Miridae) on tobacco leaves, *Bull. Entomol. Res.* **86**: 123–128.

Gautam, R. D. (1990a) Influence of substrata and age of *Coccinella septempunctata* on its oviposition, *Indian J. Agri. Sci.* **60**: 293–996.

Gautam, R. D. (1990b) Mass-multiplication technique of coccinellid predator, lady bird beetle *(Brumoides suturalis)*, *Indian J. Agri. Sci.* **60**: 747–750.

Hedge, M. and Patil, B. V. (1995) Mass rearing of phytoseiid mite, *Amblyseius longispinosus* (Evans) on cotton red spider mite, *Tetranychus maefarlanei* Baker and Pritchard, *J. Biol. Control* **9**: 54–55.

Inoue, (1985) Group predatory behaviour by the assassin bug, *Agriosphodrus dohrni* Signoret (Hemiptera: Reduviidae), *Res. Popul. Ecol.* **27**: 225–564.

Kalyanasundaram, M. (1992) Mass production of *Corcyra* and *Trichogramma*, In: *Summer Institute on Mass production of Biocontrol Agents* held between 7–22 June 1996 at CPPS, Coimbatore, 53–69.

Karuppachamy, P., Mohansundaram, M. and Jayaraj, S. (1998) A new method of mass rearing of predatory phytoseiid mites in the laboratory, *Curr. Sci.* **57**: 379–380.

King, E. G. and Morrison, R. K. (1984) Some system of eight entomophagous arthropods, In: *Advances and Challenges in Insect Rearing*, King, E. and Leppla, N. C.: (Editors). USDA-RAS, Southern Region: New Orleans, LA, 206–222.

Long, D. P. and Zaher, M. A. (1958) Effect of larval population density on the adult morphology of two species of Lepidoptera, *Plusia gamma* L. and *Pieris brassicae* L., *Entomol. Expl. Appl.* **1**: 161–173.

McPherson, R. M., Smith, J. C. and Allen, W. A. (1982) Incidence of arthropod predators in different soybean cropping systems, *Environ. Entomol.* **11**: 685–689.

Murdiels, G. (1969) The biological consequences of decreased size by crowding or rearing temperatures in apterae of the pea aphid *Acyrthosiphon pisum* Harris, *Trans. R. Entomol. Soc. Lond.* **121**: 443–445.

Naranjo, S. E. and Stimac, J. C. (1987) Plant influences on predation and oviposition

by *Geocoris punctipes* (Hemiptera: Lygaeidae) in soybeans, *Environ. Entomol.* **16**: 182–189.
Sahayaraj, K. (1995) Bioefficacy and prey size suitability of *Rhynocoris marginatus* Fabricius to *Helicoverpa armigera* Hubner of groundnut, *Fresenius Envir. Bull.* **4**: 270–278.
Snodgrass, G. L. and McWilliam, R. (1992) Rearing the tarnished plant bug(Heteroptera: Miridae) using a tissue paper oviposition site, *J. Econ. Entomol.* **85**: 1162–1166.
Watson, T. F. (1964) Influence of host plant condition on population increase of *Tetrancychus telerium* (L) (Acarina: Tetranychidae), *Hilgardia* **35**: 273–322.
Whitcomb, W. H. (1994) Environment and habitat management to increase predator population, In: *Pest Management in the Subtropic*, Rosen, D., Bennet, F. D. and Chpinera, J. H.: (Editors). Intercept: Andover UK, 149–180.
Yadav, D. N., Joshi, B. C. and Parasara, U. A. (1998) Mass rearing technique for two chrysopid predators *Chrysoperla carnea* Steph. and *Mallada boniinensis* Okamoto, In: *Technology in Biological Control*, Ananthakrishnan, T. N.: (Editor). Oxford & IBH Publishing Co. Pvt. Ltd.: New Delhi, 24–36.

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Taxonomic Studies on Four New Species of Chalcidoidea (Hymenoptera) of Economic Importance From Kashmir, India

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ABSTRACT: Four new species of Chalcidoidea *viz. Macromesus harithus* Narendran sp. nov. *Heydenia indica* Narendran sp. nov., *Eupelmus kashmiricus* Narendran sp. nov. and *Eupelmus valsus* Narendran sp. nov. parasitic on *Scolytus* sp. (a pest of apple) are described from Kashmir, India. Three Palearctic species *viz. Euplemus vindex* Erdos, *Eurytoma morio* Botuman and *Rhapitelus maculatus* Walker parasitic on *Scolytus* are recorded for the first time from Indian subcontinent.

KEYWORDS: New species, *Euplemus, Macromesus* and *Heydenia*, India.

INTRODUCTION

The apple tree *Malus silvestris* (Linnaeus) (Family:Rosaceae) is widely cultivated in Kashmir. An indetermined species of shot-hole bark beetle *(Scolytus*sp.) is found to be a pest of this tree in Kashmir. Four species of Palearctic Chalcidoidea *viz. Cheiropachus quadrum* (Fabricius) (Pteromalidae) (new record from Kashmir), *Rhaphitelus maculatus* Walker(Pteromalidae), (new record for India) *Eurytoma morio* Boheman (Eurytomidae)(new record for India) and *Eupelmus vindex* Erdos (Euplemidae)(new record for India) are found parasitising the larvae or pupae of this pest. Apart from these parasitoids, two new species of Pteromalidae and two new species of Eupelmidae *viz. Macromesus harithus* Narendran sp. nov., *Heydenia indica* Narendran sp. nov., *Euplemus kashmiricus* Narendran sp. nov. and *Euplemus valsus* Narendran sp. nov. are also found parasitising this short-hole bark beetle of apple in Kashmir. Mani and Kaul (1973) reported erroneously a species of *Macromesus viz.*

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Macromesus gardeneri Mani & Kaul from India. Boucek *et al* (1979) transferred this species to the eupelmid genus *Eusandalum* Ratzeburg, although stated that the genus *Macromesus* is 'probably represented in India'. However Graham (1969) had reported that an undescribed species of *Macromesus* is known to him from India. Since then this is the next report of the genus from India. Boucek *et al* (1979) reported an indetermined *Heydenia* from Tamil Nadu and Sri Lanka. Sureshan (2000) described *Heydenia tuberculata* from Kerala (India) without host record.

ABBREVIATIONS USED

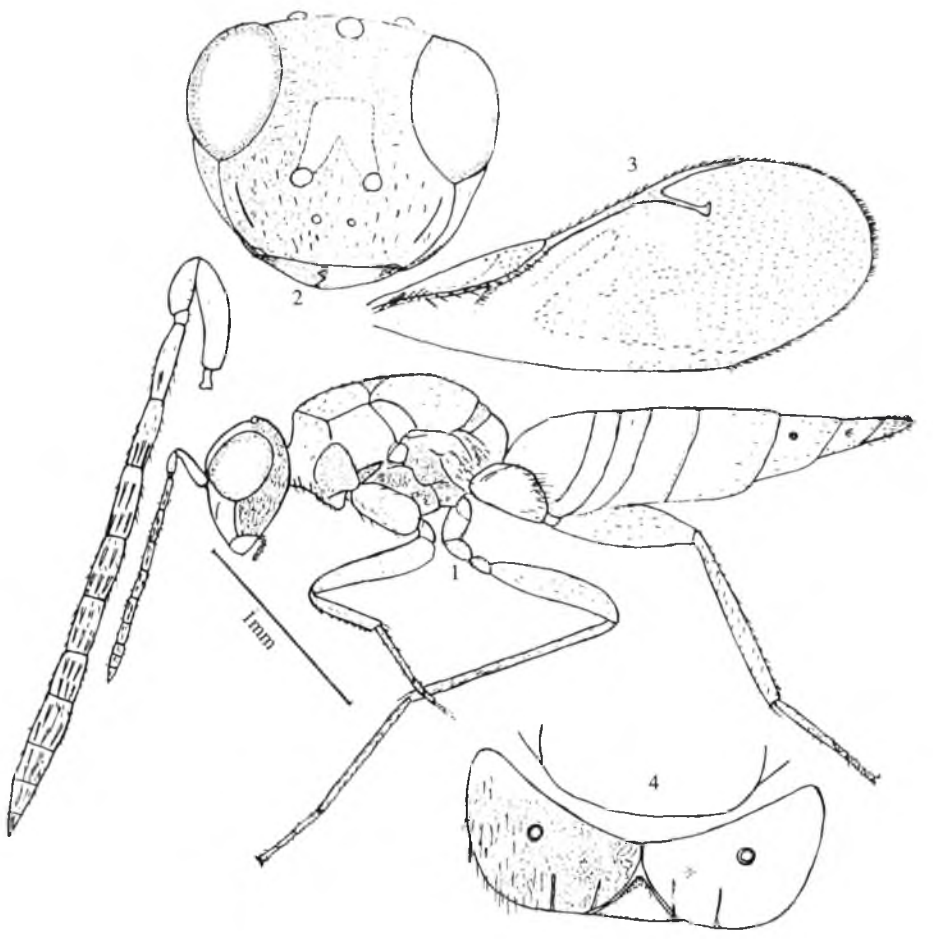
MS = Malar sulsus. OOL = Ocellocular distance; POL = Postocellar distance; SMV = Submarginal vein; MV = Marginal vein; PMV = Post marginal vein: STV = Stigmal vein; DZCU = Dept. of Zoology, University of Calicut.

1. *Macromesus harithus* Narendran sp. nov. (Figs 1–4)

Holotype Female: Length 3.52 mm. Metallic green with following parts as follows:space near ventral margin of eye, anterior region of pronotal panel and sides of gaster with bluish violet reflections; ventral region of face dark brown, mandibles black; eyes greyish yellow; ocelli pale reflecting yellow; antenna blackish brown with scape pale yellow; pedicel and anellus pale brown; all legs yellow with a slight brownish tinge; tegula pale yellowish brown; gaster greenish black with bluish violet reflection on sides. Wings hyaline with veins and pilosity blackish brown.

Head: Width in front view a little more than 1.3 × (84 : 61) distance between front ocellus and lower clypeal margin; head width in dorsal view a little more than 2.4× its median length (88 : 36), POL 1.2× OOL. MS strong; lower face with additional sulcus parallel to MS but not reaching base of mandible; head with fine reticulations on frons, vertex and face. Vertex and face with scattered small setigerous punctures; both mandibles with three teeth each (Inner tooth somewhat obtuse); lower margin of clypeus entire; anterior tentorial pits distinct; gena rugulose; posterior margin of gena ecarinate; maximum diameter of eye in profile 2× length of MS in side view. Scrobe deep, smooth with margins ecarinate, not reaching front ocellus. Antennal formula 11173. Relative length : width of antennal segments; scape 30 : 8, pedicel = 16.6, anellus 4 : 4; F1 = 21 : 5, F2 = 19 : 5, F3 = 19 : 6, F4 = 17 : 6, F5 = 15 : 7; F6 = 13 : 7.5; F7 = 14 : 8; clava = 25 : 8.

Mesosoma: Strongly reticulate on dorsum of pronotum, mesoscutum, scutellum and on dorsellum. Notauli deep and complete converging strongly towards scutellum; middle lobe of mesoscutum a little shorter than scutellum (9 : 10); dorsellum with reticulation similar to those of mesoscutum and scutellum; prepectus relatively smaller, loosely covering a narrow gap between mesoscutum and anterodorsal corner of mesopleuron. Propodeum(Fig. 4) with a short median carina bifurcating posteriorly; plicae present only popsteriorly; spiracles subcircular; fimbriae as in Fig. 4, surface finely reticulate cum shiny. Legs slender with a few dorsal spines on dorsal margin of short fore tibia; mid tarsus only four segmented, the first segment being unusually



FIGURES 1–4: *Macromesus harithus* Narendran sp. nov. Female, (1) Body profile; (2) Head front view; (3) Forewing; (4) Propodeum.

long, fore and hind tarsi five segmented; fore coxa nearly as long as hind coxa. Forewing (138 : 55) a little less than 2.5× as long as its maximum width; relative lengths of forewing veins: SMV = 53, MV = 34, PMV = 23, STV = 14; stigma and speculum as in Fig. 3; basal stub of parastigma with hairs continuing to base of wing, basal cell otherwise bare; marginal fringe of hairs going around apex of fore wing.

Gaster: Length 1.85× length of mesosoma, collapsing dorsally, polished with sparse pubescence which become denser towards posterior side.

Male: Length 1.29–1.4 mm. Resembles female except in having antennal formula 1182; funicular segments more or less stouter. Gaster 1.33× as long as mesosoma.

Holotype: Female. India, Kashmir, Srinagar; 6.x.1999.A.A. Buhroo (DZCU). Paratypes: 8 females and 2 males of same data as that of Holotype (DZCU)

Host: *Scolytus* sp. (Coleoptera:Scolytidae) on *Malus silvestris* (Linnaeus)

Discussion

This new species does not fit to the keys of Ghesquire (1963) and of Hedquvist (1960). This new species resembles the Australian species *Macomesus fulvicoxa*(Girault) (Girault, 1923; Boucek, 1988) in the colour of legs. However *fulvicoxa* differs from *harithus* in having

1. Forewing a little more than 3.2× its maximum width (in *harithus* forewing a little over 2.6× its maximum width)
2. MV a little longer than 1.33 × pm (in *harithus* a little more than 1.47 × lengthofPMV)
3. SMV with fewer number of setae than those of *harithus*
4. Costal cell of forewing without any ventral (except on margin) or dorsal setae (in *harithus* with setae in distal half as in Fig. 1);
5. Clava as long as F3 (in *harithus* distinctly larger than f3 (25 : 19)
6. F1 length 1.6× or little more than 1.6× length of pedicel (in *harithus* F1 a little more than 1.3× length of pedicel).
7. Gaster 2× or a little more than 2× as long as mesosoma (in *harithus* distinctly less than 2× as long as mesosoma)

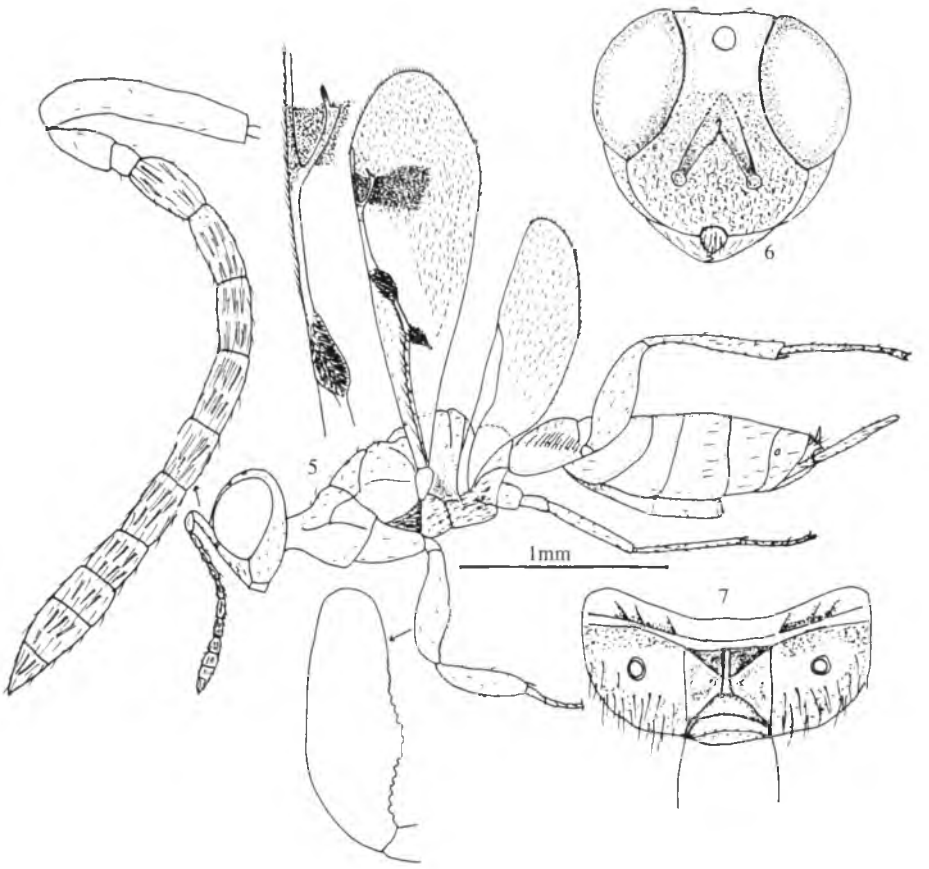
Macromesus amphiretus Walker differs from *harithus* in having

1. Stigma of forewing larger (not larger in *harithus*)
2. maximum length of female 2 mm (in *harithus* maximum length of female 3.5 to 4.2 mm)
3. Basal cell with a line of very small hairs between SMV and basal line of setae (in *harithus* no such line of setae present)
4. PMV equal to MV (in *harithus* PMV distinctly shorter than MV)
5. F1 length 3.5× its width (in *harithus* F1 2× as long as its width).

Macromesus filicornis (Del.) Ghesq., *Macromesus africanus* Ghesq. and *M. americanus* Hedquvist do not come near *M. harithus* Narendran sp. nov.

2. *Heydenia indica* Narendran sp.nov. (Figs. 8,9)

Holotype Female: Length 3.37 mm (including ovipositor sheath). Head and mesosoma metallic green except on the following parts: antenna brownish black with scape pale brownish yellow (except a dark brown patch on dorsal part at apex of scape); mandibles brownish black; maxilla and labium pale yellow; eye pale yellowish brown; ocelli pale reflecting yellow with dark patch on sides of hind ocelli; cervix, lateral panel of pronotum, pale brownish yellow. Legs pale brownish yellow with



FIGURES 5–7: *Heydenia indica* Narendran sp. nov. Female. (5) Body profile; (6) Head front view; (7) Propodeum.

apices of fore and mid femora, all tibia, dark brown (except pale yellow apices of mid and hind tibiae).Hind coxa pale brownish yellow with slight metallic green patch on dorsal side at basal half; hind femur pale brownish yellow; all tarsi whitish yellow. Gaster black with metallic green reflection with a yellow brown subbasal, part; ovipositor sheath black. Wings hyaline with dark infumation near PMV and STV (Fig. 5) and with 2 black spots (each spot shiny), one on base of MV and another on parastigma (Fig. 5).

Head: With vertex narrow, 0.28× width of head; head width in dorsal view 2× its median length; width in front view a little more than 1.3× distance between front ocellus and lower clypeal margin. POL 2× OOL; frons only superficially reticulate, shiny, but parascrobal area deeply reticulate. Vertex, genae and occipital area distinctly reticulate; clypeus with anterior margin distinctly emarginate with lobe

of epipharynx distinctly projecting as an oval thin lobe with dense setae (Fig. 6); eyes bare, its maximum diameter a little more than 3.6× length of malar sulcus in side view. Antennal formula 11173. Relative measurements of length : width of antennal segments : scape = 56 : 10, pedicel-19 : 9, anelus = 8 : 7, F1 = 21 : 11, F2 = 20 : 9, F3 = 20 : 9, F4 = 20 : 9, F5 = 17 : 10, F6 = 18 : 10, F7 = 14 : 10, clava = 39 : 13.

Mesosoma: Pronotum and mesoscutum densely reticulate; length of mesoscutum a little more than its width; notauli wide apart, distinct and complete. Scutellum a little longer than its maximum width (11 : 10), anterior half convex. Propodeum with median carina as in Fig. 7; submedian areas mostly smooth and shiny. Prepectus distinctly reticulate; mesopleuron reticulate except for a small smooth area near tegula; metapleuron reticulate-punctate with dense silvery pubescence on posterior part; fore and hind femora enlarged with distinct serration and spines respectively as in Fig. 5. Forewing with MV a little less than 2× PMV.

Gaster: Subsessile with a very short petiole; length of gaster (exceeding ovipositor sheath) 1.32× length of mesosoma. Relative proportion of length : width of petiole 1 : 4, gaster collapsing from dorsal side. T1 and T2 very slightly sinuate on posterior margin; ovipositor sheath (in side view) a little over 0.65× length of hind tibia; ovipositor sheath in dorsal view 0.55× length of hind tibia.

Male: Length 2.47 mm. Similar to female except in having shorter gaster (1.41× length of mesosoma) with narrow subquadrate pale petiole. T1 and T2 with posterior margins straight

Holotype: Female. INDIA : Kashmir, Srinagar, 6.x.1999, A.A Buhroo (DZCU). Paratypes: 2 Females and 1 male of same collection data as that of Holotype (DZCU).

Discussion

H. indica comes to couplet No. 3 of key to species by Hedquvist (1957) but differs from *Heydenia pretiosa* Foerster and *Heydenia unica* Cook and Davis in having:

1. Ovipositor sheath (in dorsal view) 0.55× length of hind tibia (in *pretiosa* and *unica* ovipositor sheath less than 0.3× length of hind tibia
2. Flagellar segments not gradually widening from 1 to F7 (gradually widening in *pretiosa* and *unica*)
3. SMV 2.6× as long as MV (SMV at the most 2× as long as MV in *pretiosa* and *unica*)
4. Length of scape a little more than 2.6× length of F1 (not so in *pretiosa* and *unica*)
5. Propodeum as n Fig. 7 (not so in *pretiosa* and *unica*)
6. Serration of fore femur much longer than those of *pretiosa* and *unica*)
7. In female all coxae pale brownish yellow with a slight metallic green patch on a small area on dorsal side of basal half of hind coxa (in *pretiosa* and *unica* colour of coxae different (Boucek, 1958) synonymized *Lycisca silvestris* Russo with *H. pretiosa* Forster).

The Australian species *Heydenia longicollis* Cameron and *Heydenia cristatipennis* (Girault) differs from *H. indica* in having

1. Petiole distinctly visible from dorsal side, about as broad as long (petiole not distinctly visible and 4× as broad as long in *indica*);
2. Length of ovipositor sheath in dorsal view 0.1 to 0.15× length of hind tibia (in *indica* 0.55× length of hind tibia)
3. Length of gaster a little over 1.4× length of mesosoma (in *indica* 1.3× length of mesosoma)
4. Mesoscutum length in female about 1.3× its median length. (in *indica*, a little more than 1.8× its median length)
5. Length of calva in female 4 to 5× length of F7 (in *indica* clava much shorter than 3× length of F7). And relative proportions of antennal segments and nature of propodeum also differ greatly between *indica* and other mentioned two species (*longicollis* and *cristatipennis*).

The species *Heydenia trinodis* Boucek from Papua New Guinea (Boucek, 1988) differs from *H. indica* in having

1. Axillae smooth and shiny (reticulate in *indica*)
2. Ovipositor about 1.2× hind tibia (in *indica* only 0.65× hind tibia)
3. F1 almost 2× length of pedicel (distinctly shorter than 2× of pedicel in *indica*)
4. Propodeum with weak plicae (with strong plicae in *indica*)
5. Petiole about 2× as broad as long (4× as broad as long in *indica*)

Heydenia burgeoni (Risbec) from Africa differs from *Heydenia indica* in having ovipositor sheath longer than hind tibia and axillae is more advanced and in having vaguely indicated notauli.

KEY TO INDO-AUSTRALIAN SPECIES OF *HEYDENIA*

(Based on females)

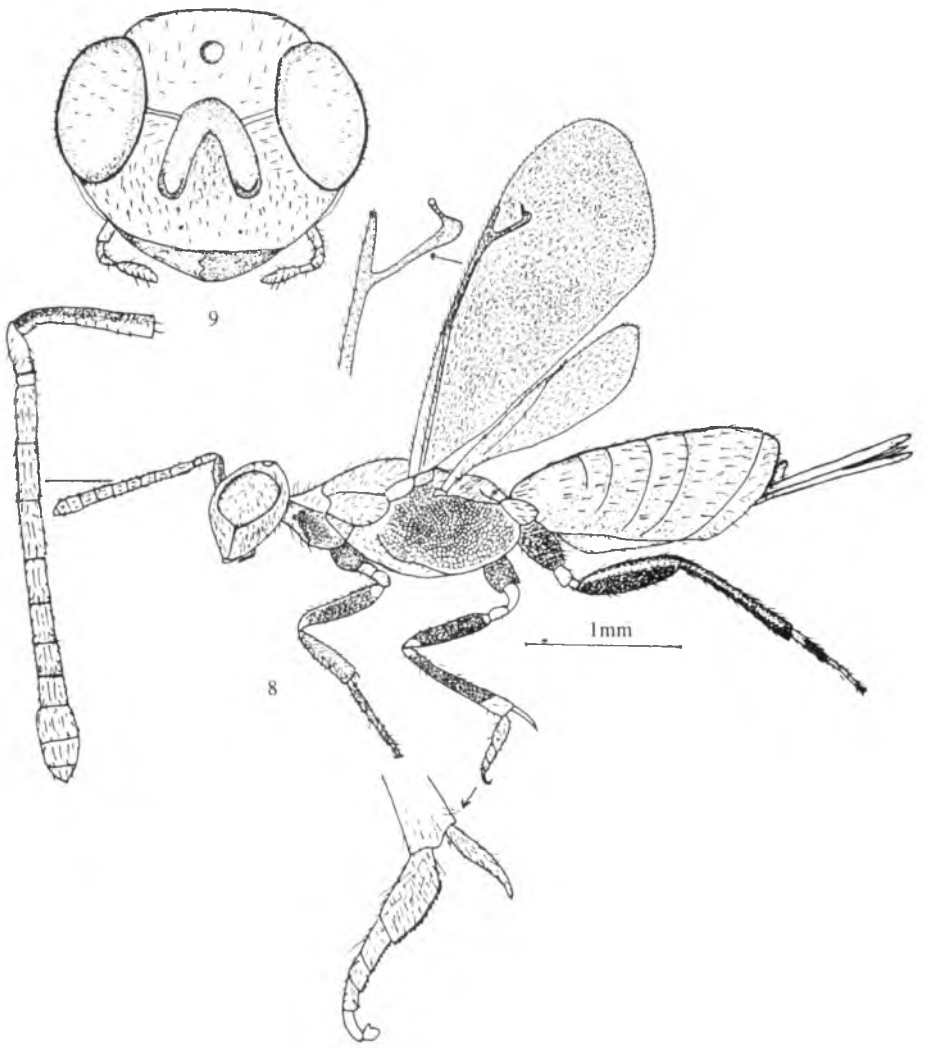
1. Axillae smooth and shiny 2
   Axilla reticulate 3
2. Median carina of propodeum with an anteriorly curved small sharp teeth; ovipositor sheath about half as long as hind tibia; India ..... *TUBERCULATA* Sureshan
   Median carina of propodeum without teeth or tubercle; ovipositor sheath about 1.2× length of hind tibia. Papua New Guinea ..... *TRINODIS* Boucek
3. Ovipositor sheath in dorsal view 0.55× length of hind tibia; petiole width about 4× its length, hardly visible from dorsal side; clava shorter than 3× length of F7 ..... *INDICA* Narendran sp. nov.
   Ovipositor sheath in dorsal view 0.1 – 0.15× length of hind tibia; petiole longer than in alternate, clearly visible; clava not as in above alternate 4
4. Scutellum flat ..... *LONGICOLLIS*(Cameron)
   Scutellum convex ..... *CRISTATIPENNIS*(Girault)

3. *Eupelmus kashmiricus* Narendran sp. nov. (Figs 8–9)

Holotype Female: Length 4.2 mm. Black with metallic green refringence; coppery refringence on upper frons, vertex, gena, scapulae, mesoscutum and on scutellum. Antenna black with scape pale yellow on inner side. Fore coxa concolorous with mesosoma, trochanter pale brownish yellow, fore femur pale yellow inside and dark brown outside; fore tibia pale yellow inside and darker outside; tarsi brownish black. Middle coxa concolorous with mesosoma; trochanter pale yellow; mid femur and tibia black with bases and apices whitish yellow; pegs at apex of mid tibia black; mid tarsi pale yellow with pegs black;. Hind coxa concolorous with mesosoma; hind femur and tibia black with a dorsal yellow streak; hind metatarsus black with base yellow, remaining tarsal segment pale brownish yellow; pretarsus black. Gaster black with metallic green reflection; ovipositor sheath pale yellow without black bands. Wings more or less uniformly infuscate; veins pale brown; pubescence on head and body silvery.

Head: Reticulate, densely pilose, width in dorsal view a little less than 6× distance between front ocellus and occipital margin. POL a little less than 2× OOL(12 : 55). Eyes with short moderately scattered pubescence; maximum distance of eye in profile 2.12× length of MS; genal region posterior to Ms strongly reticulate and with moderately dense pubescence. Scrobe deep, smooth, side margins carinate, upper margin ecarinate with a characteristic distinct sulcus on either side of scrobe, connecting scrobe to circumocular sulcus (Fig. 9). Antennal formula 11173. Relative measurement of length : width of antennal segments:scape = 38 : 6; pedicel = 15 : 5; anellus = 5 : 4; F1 = 15 : 5, F2 = 15 : 5; F3 = 15 : 6; F4 = 12 : 5; F5 = 11 : 5; F6 = 9 : 6.5; F7 = 8 : 7; clava = 20.5 : 11. Antennal segments pubescent.

Mesosoma: Pronotum densely reticulate with a median shallow groove; mesoscutum closely reticulate, its length almost subequal to its maximum width; notauli distinct, widely separated posteriorly, not quite reaching transcutal sulcus; median lobe of mesoscutum 0.53× as long as mesoscutum; scutellum and axillae distinctly and closely reticulare; axillae almost meeting anteromedially; apex of scutellum rounded; metanotum with dorsellum narrow; propodeum without median carina, moderately reticilate, callus separated by plical furrow, posterior margin carinate; prepectus and mesopleuron as in Fig. 8 . Macropterous; forewing more or less uniformly infuscate throughout, a little shorter than length of gaster (including ovipositor sheath), a little more than 2.7× as long as its maximum width. Relative measurements of length of forewing veins: SMV = 38;MV = 30, PMV = 7.1 ; STV = 12. Mid tibial spur subequal in length to mid tarsus; double rows of pegs present on ventral side of mid metatarsus, each row with 17 pegs; second tarsal segment of midleg with 6 ventral pegs on each row; thiord segment of midleg with 3 pegs on each ventral row; fourth tarsal segment of midleg with one peg on ventral side of each row; fifth tarsal segment of midleg, without pegs; length of hind metatarsus as long as following three segments combined.



FIGURES 8–9: *Eupelmus kashmiricus* Narendran sp. nov. Female (8) Body profile; (9) Head front view.

Gaster: length (excluding ovipositor sheath) a little longer than 1.3× length of mesosoma; T1 incised slightly medially, gaster collasping from dorsal side; T5 longest; T6 medially divided; ovipositor sheath a little longer than 1.3× hind tibia in side view (Fig. 8) a little more than 0.6× length of remaining part of gaster.

Male: Unknown.

Host: *Scolytus* sp. on *Malus silvestris* (Linneaus)

Holotype: Female. INDIA, Kashmir, Srinagar. 6.x.1999. A.A. Buhroo (DZCU,T.C. Narendran collection). Paratype 2 females of the same data of Holotype (DZCU)

Discussion

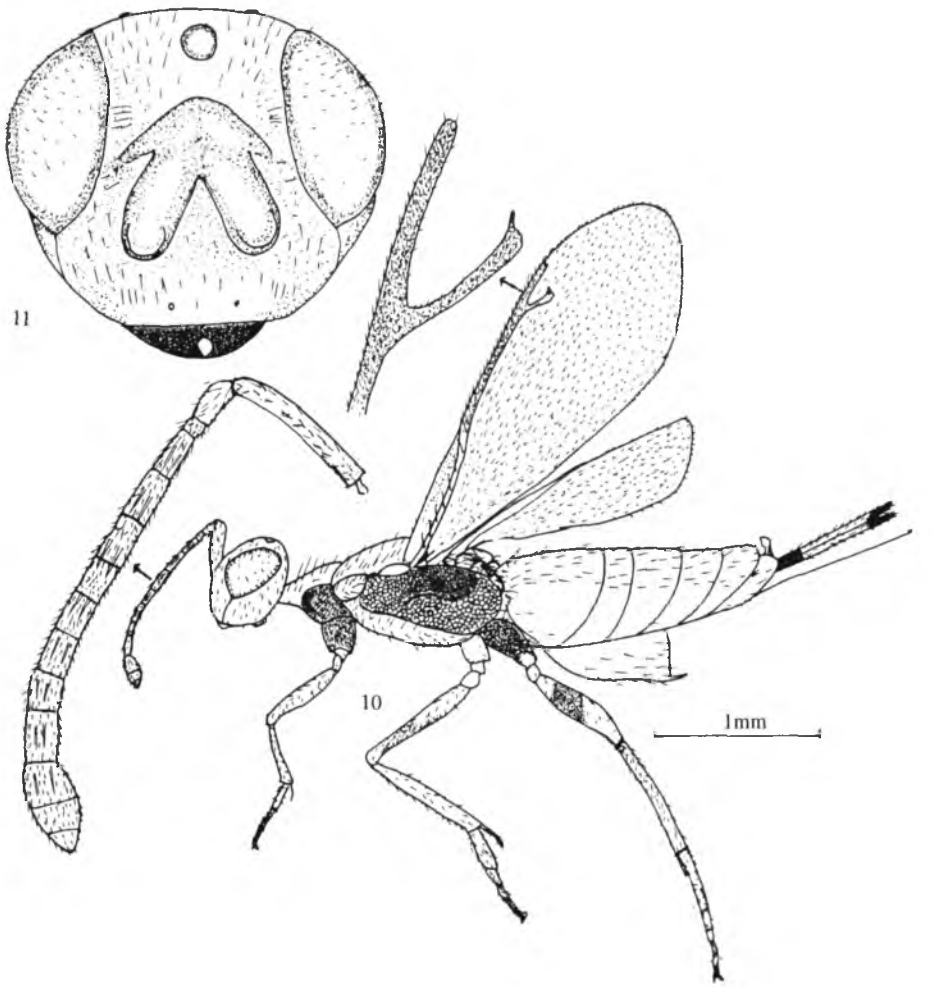
This species does not fit to the keys of Nikolskaya (1952), Tryapitzin (1978) and Narendran and Anil (1995). This new species deffers from all the other known species of *Eupelmus* in having a distinct sulcus connecting scrobe and circumocular sulcus on either side of scrobe; STV with a characteristic tip, PMV distinctly shorter than STV (7.1 : 12), forewing uniformly infuscate without speculum and forewing densely pilose.

4. *Eupelmus valsus* Narendran sp. nov. (Figs 10–11)

Holotype Female: Length 4.08 mm. Dark metallic green. Eyes grey; front ocellus pale yellow; hind ocelli black, mandibles black; fore and hind coxae concolorous with mesosoma; fore femur, fore tibia, fore metatarsus, second tarsus of foreleg pale yellow; remaining tarsal segments of fore leg black; mid femur pale yellow with dark brown colour at apical patch, pegs on tarsi black, fifth tarsal segment of midleg black; hind femur pale yellow with dark brown colour at apical part; pegs on tarsi black; fifth tarsal segment of midleg black; hind femur pale yellow with dark brown patch in middle (more towards base), (Fig. 10); hind tibia and tarsi (except black 5th segment) pale yellow; ovipositor sheath yellow with base and apex black; forewiing hyaline, not infuscate, veins pale brown. Pubescence on head and body silvery.

Head: Finely reticulate, densely pubescent, width in dorsal view 4.12× distance between front ocellus and occipital margin; POL 3.27× OOL. Eyes with short scattered pubescene; maximum diameter of eye in profile 2.5× length of MS; genal region posterior to MS reticulate with moderately dense pubescence; scrobe deep, smooth margins ecarinate but strongly edged with a deep break projecting to parascrobal area (Fig. 11). Antennal formula 11173. Relative measurements of length:width of antennal segments:scape = 39 : 5, pedicel = 12 : 6; F1 12 : 5; F2 = 12.5 : 6; F3 = 12.5 : 7; F4 = 10 : 7; F5 = 10 : 7; F6 = 10 : 7; F7 = 10 : 7; F8 = 12 : 8; clava = 24 : 12. Antenna with dense short pubescence.

Mesosoma: Pronotum reticulate with a median shallow sulcus, mesoscutum distinctly reticulate, its length subequal to its maximum width; notauli distinct widely separated posteriorly and not reaching trans-scutal sulcus; median lobe of mesoscutum 0.53× as long as mesoscutum; scutellum and axilla reticulate; axillae almost meeting anteromedially; apex of scutellum rounded at apex; metanotum with dorsellum narrow; propodeum faintly reticulate without a median carina; callus separated by plical furrow, posterior margin carinate; prepectus and mesopleuron as in Fig. 10; mesopleuron with a wavy shallow line. Macropterous; forewiing hyaline, not infuscate, subequal in length of gaster (including ovipositor sheath), 2.74× as long as its maximum width.Relative measurement of lengths of forewiing veiins: SMV = 37; MV = 35; PMV = 11; STV = 7.9. Mid tibial spur shorter than mid tarsus; mid tarsus



FIGURES 10–11: *Eupelmus valsus* Narendran sp. nov. Female (10) Body profile; (11) Head front view.

with a double row of pegs, each row with 15 pegs, second mid tarsus with 6 pegs on each row; third mid tarsus with 3 pegs on each row, fourth tarsal segment with a single peg on either side; fifth without any peg. HInd metatarsus longer than combined length of rest of hind tarsal segments.

Gaster: Length (excluding ovipositor) 1.11× length of mesosoma; T1-T4 incised medially; T6 medially divided with median sternite lifted upwards; ovipositor sheath a little longer than 0.47× remaining part of gaster, a little longer than hiind tibia (32 : 31).

Male: Unknown

Host: *Scolytus* sp.(Coleoptera: Scolytidae) on *Malus silvestris* (Linneaus)

Holotype: Female, India; Kashmir, Srinagar, 6.X.1999 A.A. Buhroo (DZCU)

Discussion

This new species as in the case of former species (*E. kashmiricus*) does not fit into the keys of Nikolskaya (1952); Tryapitzin (1978) and Narendran and Anil (1995). It resembles *E. kashmiricus* Narendran sp. nov. in having dense pubescence on body. However *E. valsus* Narendran sp. nov. differs from *E. kashmiricus* in having

1. Side margins of scrobe broken and as in Fig. 11. (In *kashmiricus* scrobe margin not as above)
2. Without sulci connecting scrobe and circumocular sulcus (in *kashmiricus* scrobe is connected to circumocular sulcus by a fovea on either side)
3. A line of depression on mesopleuron (in *kashmiricus* no such line present) and in several other features.

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REFERENCES

Boucek, Z. (1988) *Australasian Chalcidoidea (Hymenoptera)*, C.A.B. International: Wallingford, U.K., 832.

Boucek, Z., Subba, Rao and Farooqi, S. I. (1979) A preliminary review of Pteromalidae (Hymenoptera) of India and adjacent countries, *Orient. Insects.* **12**: 433–467.

Boucek, Z. (1958) Eine Cleonyminen-studie; bestimmungsstablle der gattungen mit beschreibungen und notixen eingeschlossen einige Eupelmidae (Hymenoptera: Chalcidoidea), *Acta.ent. Mus. Natn. Pragae* **32**: 353–386.

Ghesquire, J. (1963) Le genere *Macromesus* Walker nouveau pour la faune africaine, *Rev. Zool. Bot. Afr.* **67**: 81–90.

Girault, A. A. (1925) Indications (in new insects) of ruling power and law in nature, In: *The privately printed papers of A. A. Girault. The Memoirs of Amincan Entomological Institute*, Gord, G., Menki, A. S., Dahms, E. C. and Hall, J. C.: (Editors). **28**: 1–400.

Graham, M. N. R. and de, V. (1969) The Pteromalidae of North Western Europe (Hymenoptera:Chalcidoidia), *Bull. Br. Mus. Nat. Hist. Ent. Suppl.* **16**: 1–908.

Hedquvist, K.-J. (1957) Uber die gattung *Heydenia* Forst Chym: Chalc.), *Opusc. Ent.* **22**(1): 39–47.

Hedquvist, K. -J. (1960) Notes on *Macromesus* Walk (Hym. Chalcidoidea, Pteromalidae) and descriptions of a new species, *Entomol Ts. Agr.* **81**: 3–4.

Mani, M. S. and Kaul, B. K. (1973) In Mani, M. S., Dubey, O. P., Kaul, B. K and Saraswat, C. G. On some Chalcidoidea from India, *Mem. Sch. Ent, St. John's Coll.* **2**: 1–128.

Narendran, T. C. and Anil, K. (1995) A key to Indian species of *Eupelmus* Dalman (Hymenoptera: Eupelmidae) with descriptions of eleven new species, *J. Zool. Soc.Kerala.* **5(1&2)**: 1–75.

Nikolskaya, M. N. (1952) The chalcid fauna of U.S.S.R. (Chalcidoidea) Opredeliteli po Faunae SSSR, **44**: 1–575 (Translated from Russian by Isreal programme for scientific Transalation, 1963).

Sureshan, P. M. (2000) A new species of *Heydenia* Foerster (Hymenoptera: Pteromalidae) from India, **15**: 197–198.

Tryapitzin, V. A. (1978) Hymenoptera (part. 2). (In Russian). Opredelitel Naekomykh Europeiskoi Chasti SSR [Key to Insects of the European USSR], **3**(2): 1–758 (Translated and published for the United states Department of Agriculture, Washington D.C. by Amerind publishing Co. Pvt. Ltd. New Delhi, 1987).

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Laboratory Observations on the Life and Fecundity Parameters of the Red Cotton Bug *Dysdercus koenigii* (Heteroptera: Pyrrhocoridae)

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ABSTRACT: The life and fecundity parameters of *Dysdercus koenigii* were observed through 5 generations using various biotic characters like mortality at every stage of its life cycle, nymphal periods, adult longevity, fertility (total ♂ & ♀), fecundity and sex ratio. Generation survivability was recorded from 8.00 to 23.73%. Maximum mortality at egg stage was 53.08%; at 1st, 2nd, 3rd, 4th, and 5th instar stage it was 34.69, 43.75, 31.71, 35.29, 20.83% respectively; and the adult stage it was 30.00%. Fertility and sex ration of both the sexes varied from 4.8 to 24.89 (♂ ♀) and 1 to 1.8 in ♀s and 1 to 1.5 in ♂s respectively. The insect population decreased in the last generation about half time of the first generation.

Growth and differentiation of *Dysdercus koenigii* were recorded during the time of insect development through various stages (Egg-E, Instar-1st to 5th-I_1-I_5, adult-A & Dead-D), which was found as 00.00, 5.6±0.44, 5.8±0.52, 6.0±0.48, 7.0±0.63, 9.4± 0.75 and 40 ± 4.40 days respectively.

KEYWORDS: *Dysdercus koenigii*, life, fecundity, fertility, Growth and differentiation.

INTRODUCTION

A life and fecundity table is a convenient way of describing insect population dynamics. Age specific life tables are known as horizontal, dynamic or cohort life tables (Harari *et al*, 1997). Such tables describe the developmental time and survival rate of each stage. Further, in combination with the fecundity data per gonadotrophic cycle (generation), these tables might predict the population size of an insect pest and its age structure for any given time (Southwood, 1978). In most of the insect species, the mortality rate is a characteristic of the stage that is not uniform for all the developmental stages (Ricklefs, 1963; Southwood, 1978; Harari *et al*, 1997; Martinez and Katthain, 1999). A knowledge of the number of immature stages of a given insect pest and the mortality factors affecting each stage thereof might assist in the

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pest management procedures (Harcourt, 1968; Southwood, 1978; Horn, 1988). Such studies help in assessing the values of various ingredients of the environment, which are responsible for maintenance of a population in nature (Bajpeyi *et al*, 1995).

The insect, *Dysdercus koenigii*, currently under investigation is commonly known as the red stainer or red cotton bug. This is a multivoltine insect having 5–6 gonadotrophic cycles in its life span, and constitutes one of the key pests of cotton and other malvaceous plants. Life table study of an insect pest is essential to utilization in developing its effective IPM (Prakash and Rao, 1999). Our aim of the present study was to determine the life and fecundity tables of *Dysdercus koenigii* under laboratory conditions that could be of some help in controlling its population through IPM.

MATERIALS AND METHODS

Maintenance of insect generation

For preparing the life and fertility tables and growth and differentiation, *Dysdercus koenigii* was maintained in the laboratory on the cotton seeds (presoaked in water) under long day (16L : 8D) photoperiod at 25 °C and relative humidity 70–80% (Venugopal *et al*, 1994). After the first egg laying, the pair of ♂ & ♀ was transferred to a separate rearing glass jar for next generation and so on.

Mortality at each stage

To record the mortality at each developmental stages of the bug of each generation, the nymphal stages were examined and the total number of eggs oviposited was noted. After hatching, the 0 day old instars were numbered and the same was deducted from the total number of the eggs laid by the insect. Thus the percentage of the unhatched eggs was calculated that was considered as the mortality during the egg stage. Mortality during the nymphal stages was calculated from the deduction between the number of penultimate instars and the next stage. Similarly adult mortality was calculated from the deduction between the number of adults emerged and the number of 5th instars.

Fertility of the female bug

On emergence five pairs of male and female bugs were randomly selected from the stock and each pair was kept in a separate glass jar for copulation and subsequent oviposition. The number of fertile bugs was recorded on the basis of hatching of eggs laid by the bugs. Survival rate of the bug at each developmental stage was assessed according to Harcourt (1968).

Growth and differentiation

For growth & differentiation the observations were recorded while the bug is developing through the various instars such as egg, instars ($I_1 - I_5$) and Adult(A = alive; D = dead). Various variables of growth & differentiation are time of

development and rate of development, which are represented by the slope of the average differentiation curve (obtained by setting 'development to a given instar' equal to 1 or 100%).

Fecundity generation

Fecundity generation was recorded on the basis of egg cycles during its total reproduction phase. The Data of fecundity table were expressed as mean ± SEM. Statistical analyses of data were performed using one-way ANOVA followed by 't' test (Bruning and Kintz, 1977).

Standard estimator for the growth rate

The standard estimator for the growth rate of insect population is the intrinsic rate of increase (r_m), which describes the maximal rate of increase at any time interval under optional conditions. The rate of deduction and multiplication of population per generation is described by the reproductive rate (R_0) that is dependent on (r_m) (Southwood, 1978).

RESULTS

The results of investigations on the life fecundity potentiality of *Dysdercus koenigii* under laboratory conditions are as follows:

A: *LIFE TABLE*

Egg Stage

Egg mortality varied from 36.99 to 53.08% in a life cycle (see Table 1).

Nymphal and adult stages

The mortality rate of the first nymphal stage was recorded as 6.52% minimal and 34.69% maximal in a life cycle. The 2nd nymphal stage had 4.35% minimal and 43.75% maximal mortality. The 3rd nymphal stage had 4.55% minimal and 31.71% maximal mortality. Mortality rate was 00% minimal and 35.29% maximal in the 4th instar stage. While this was 00% minimal 20.83% maximal in the 5th instar. The adult stage showed 11.11% minimal and 30.00% maximal mortality rate (Table 1). Growth and differentiation of various instars ($I_1 - I_5$) was recorded as 00.00, 5.6 ± 0.44, 5.8 ± 0.52, 6.0 ± 0.48, 7.0 ± 0.63, 9.4 ± 0.75 and 40 ± 4.40 days of the adult respectively (Fig. 2).

Fertility, Sex ratio, and *Generation survivability* are recorded in Table 2. According to this fertility is variable from 4.8 to 24.89%. Sex ratio was calculated from 1 to 1.8 in ♀ and 1 to 1.5 in ♂ respectively. Generation survivability varied from 8.00% (minimal) to 23.73% (maximal).

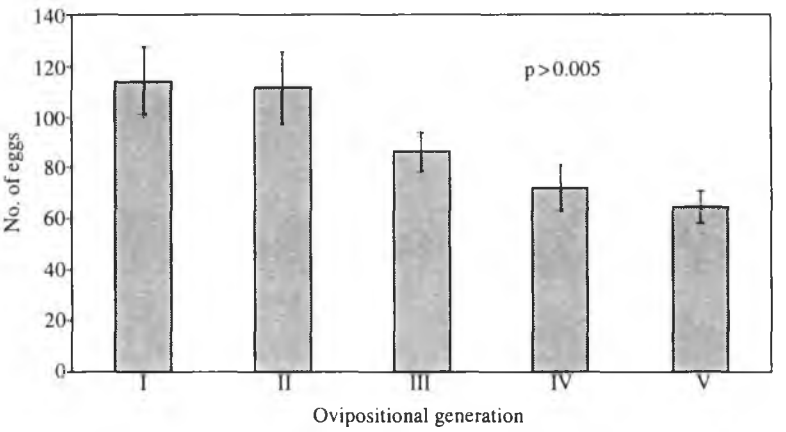

FIGURE 1. Shows histograms representing life time fecundity table of *Dysdercus koenigii*. Each Stage is the mean ± S.E.M. of five different observations. ($P > 0.005$)

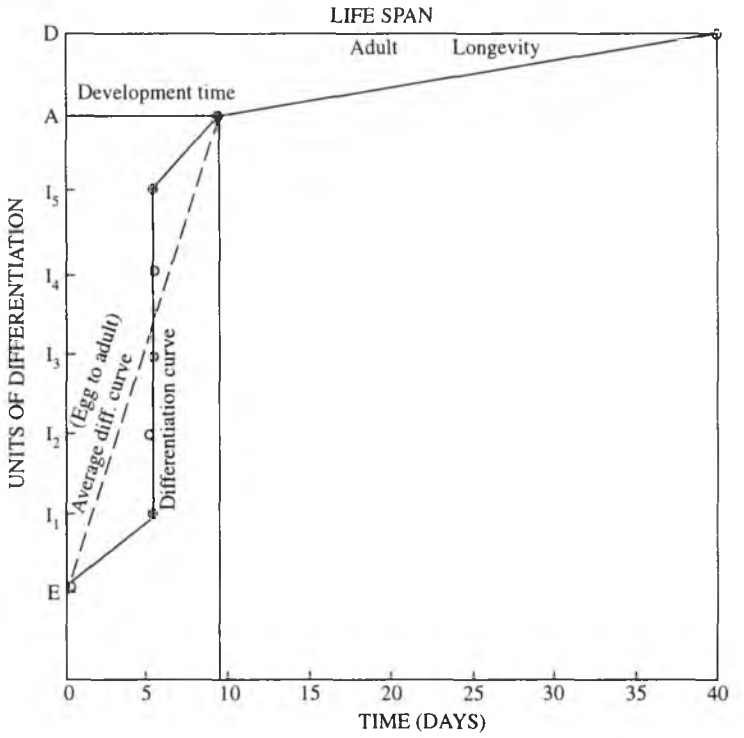

FIGURE 2. Shows the growth and differentiation of *Dysdercus koenigii*. During the postembroyonic development, the insect develops through five different instars (I) and adult (A); Death (D); variables of the growth and differentiation are time of development and rate of development. ($n = 20$).

B: *Fecundity table*

One-Way ANOVA followed by 't' test revealed that the significant reduction in the no. of eggs (fecundity) occur only in the 4th and 5th generation (Fig. 1). The fecundity potential was maximum in the first gonadotrophic cycle (generation) i.e. 114.4 ± 13.318; and a decline in the subsequent generations was observed i.e. 111.60 ± 14.634 (2^{nd} generation); 85.6 ± 7.527 (3rd generation); 71.2 ± 8.974 (4th generation); 64.00 ± 6.107 (5th generation). This was highly significant ($P < 8.062E-03)(n = 5$) (Fig. 1).

DISCUSSION

A life table is a table showing the survival, by age-class, of a cohort of individual born in one season. The study of life tables can be important in discovering the effect of survival and fecundity as the growth determinants of a population (Southwood, 1978). The present data demonstrate that fecundity of *Dysdercus koenigii* suits very well in the lab conditions showing its full fitness or reproductive potential. Of course, the fecundity of an insect is important measure of its fitness, and those variables maximally affecting fecundity are likely to be important in the behavioral ecology of the insect (Landolt, 1997). However, it awaits further investigation to pin point the most important factor(s) affecting the survival of the present insect.

During the first generation high egg mortality was observed. This could be due to several reasons. These eggs might have not been fertilized or might not have been processed properly during oogenesis (small eggs) or ovulation or there could be less yolk (Hinton, 1981) that hampers the hatching. Further, mechanical, or physical disruption to the sensitive stages could be another reason for high mortality (Harari *et al*, 1997). On the other hand, high fecundity rate observed could be due to certain abiotic factors like humidity, food, light and water that are provided sufficiently in the lab. Water constitutes one of the controlling factors for fecundity for cabbage looper (Landolt, 1997). Nevertheless, it is our common observation that removal of water vials from the rearing glass jar causes a marked decline of the fecundity and survival of *Dysdercus koenigii*.

The duration of the larval life was found to be more at the middle stages and minimum at the early development and last nymphal and adult stages in present insect species. According to Ricklefs (1963), Southwood (1978) and Martinez and Katthain (1999) in many insects the mortality rate is a characteristic of the stage and is not uniform for all the developmental stages. Hemipteran lay eggs in a cyclic order. Generally, the egg cycles and their duration are not reckoned with the parameters of the fecundity. In *Dysdercus koenigii* 5 gonadotrophic cycles were recorded in the mated females, which was completed in about a month. Number of eggs was more in the first generation that reduced subsequently in the next generations (Cf. Table 1). Similar trend has also been recorded for various insects (Mayer, 1957; Ward and Landolt, 1995; Hirschberger, 1999). However, survivability in each generation shows almost a constant feature. It increases from egg stage to a maximum up to fifth instar

TABLE 1. Life of *Dysdercus koenigii* through 5 generations.

Stage	I Generation			II Generation			III Generation			IV Generation			V Generation		
	No.	M%	S%	No.	M%	S%	No.	M%	S%	No.	M%	S%	No.	M%	S%
Eggs	130	53.08	46.92	118	44.92	55.08	100	51.00	49.00	84	45.24	54.76	73	36.99	63.01
Instar 1	61	21.31	78.69	65	29.23	70.77	49	34.69	65.31	46	6.52	93.48	46	19.57	80.43
Instar 2	48	25.00	75.00	46	4.35	95.65	32	43.75	56.25	43	4.65	95.35	37	5.41	94.59
Instar 3	36	11.11	88.89	44	4.55	95.45	18	5.56	94.44	41	31.71	68.29	17	5.88	94.12
Instar 4	32	6.25	93.75	42	4.76	95.24	17	35.29	64.71	28	14.29	85.41	16	0.00	100.00
Instar 5	30	0.00	100.00	40	0.00	100.00	11	18.18	81.92	24	20.83	79.17	16	12.50	87.50
Adult	30	23.33	76.67	40	30.00	70.00	9	11.11	88.89	19	21.05	78.95	14	28.57	71.43
Female (fertile)	14(12)		85.71	18(16)		88.89	05(3)		60.00	06(6)		100	06(4)		66.67

No. = Number, M = Mortality, S = Survivability

TABLE 2. Life table of *Dysdercus koenigii* showing fertility, sex ratio and generation survivability

Variable	1st Gen.	2nd Gen.	3rd Gen.	4th Gen.	5th Gen.
Fertility (♂ ♀)	19.71	24.89	4.8	15.00	10.00
Sex Ratio (♀ ♂)	1.6:1	1.8:1	1.6:1	1:1.5	1.5:1
Generation survivability (%)	17.69	23.73	8.00	17.85	13.70

stage. Nevertheless, this trend shows a deviation in the 5th generation wherein the maximum survivability is seen in the fourth instar stage. Adult survivability declines almost in all the generations excepting for the 3rd generation. The observed reduction in the fecundity could be due to ageing of the egg laying pair in addition to other genetic, physio-chemical and disease factors affecting the fecundity (Clark *et al*, 1967; Mohaghegh *et al*, 1998).

The fifth instar stage was found to be the most crucial stage of the development with the highest survivability. Notwithstanding, the 5th instar is the most active and destructive phase of the entire life cycle of *Dysdercus koenigii* (Singh, 1999). Destruction of this very stage by chemical or physical means would be certainly advantageous in the control management scheme of this very pest. Further, it has been observed that the female adults take 3-4 days time for maturation and copulation after the emergence and then go for egg laying. Thus there is another opportunity immediately after the adult emergence that could be targeted to control the population in the field through IPM.

We presume that the current data on life table and fecundity may assist in a better understanding of the population dynamics of *Dysdercus koenigii* in the field. This may open new gates for formulating the pest management strategies as suggested for *Maladera matrida* (Harari *et al*, 1997).

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REFERENCES

Bruning, J. L. and Kintz, B. L. (1977) Computational hand book of statistics, 2nd edn Scott, Freeman and Co. Illionois: USA.

Bajpeyi, C. M., Dubey, O. P., Kumar, A., Jayaswal, J. and Thangavelu, K. (1995) Life table studies of Tropical Tasar silkworm *Antheraea mylitta* (Lepidoptera: Saturniidae), *Entomon* **20(1)**: 59–61.

Clark, L. R., Geier, P. W., Hughes, R. D. and Morris, R. F. (1967) The ecology of insect populations in theory and practical, Methuen and Co: London.

Harari, A. R., Ben-Yakir, D., Chen, M. and Rosen, D. (1997) Life and fertility tables of *Maladera matrida* (Coleoptera: Scarabaeidae), *Environ. Entomol* **26(5)**: 1073–1078.

Harcourt, D. G. (1968) The development and use of life tables in the study of natural insect populations, *Annu. Rev. Entomol.* **13**: 175–196.

Hinton, H. E. (1981) *Biology of Insect Eggs*, Vol **1**. 473, Pergamon Press: Oxford.

Hirschberger, P. (1999) Larval population density affects female weight and fecundity in the dung beetle Aphodius ater, *Ecol. Entomol.* **24**: 316–322.

Horn, D. J. (1988) Ecological approach to pest management, Elsevier: London.

Landolt, P. J. (1997) Cabbage Looper (Lepidoptera: Noctuidae) fecundity maximized by a combination of access to water and food, and remating, *Ann. Entomol. Soc. Am.* **90(6)**: 783–789.

Martinez, J. A. and Katthain, D. G. (1999) Biology of *Triatoma pallidipennis* stall 1945 (Hemiptera: Reduviidae: Triatominae) under laboratory conditions, *Memorias –do-Instituto-Oswaldo-Cruz.* **94(6)**: 837–839 20 ref.

Mayer, H. (1957) Zur Biologie und rthologie einheimis cher Collembolen, *Zool. Jb. Syst* **85**: 501–570.

Mohaghegh, J., Clercq, P. D. and Tirry, L. (1998) Effects of maternal age and egg weight on developmental time and body weight of offspring of *Podisus maculiventris* (Heteroptera: Pentatomidae), *Ann. Entomol. Soc. Am.* **91(3)**: 315–322.

Prakash, A. and Rao, J. (1999) Age specific fecundity, Life table and intrinsic rate of increase of Malaysian black bug, *Scotinophara coarctata* Fabricius, *Entomon* **24(2)**: 191–194.

Ricklefs, R. E. (1963) *Ecology*, Thomas Nelson and Sons: London.

Singh, A. K. (1999) Certain aspects of studies on salivary gland of the red cotton bug, *Dysdercus koenigii* (Heteroptera: Pyrrhocoridae) during larval-adult transformation Ph.D. Thesis. Banaras Hindu University, Varanasi.

Southwood, T. R. E. (1978) Ecological methods with particular reference to the study of insect population, *The ELBS*. Chapman and Hall: 524, London.

Venugopal, K. J., Kumar, D. and Singh, A. K. (1994) Developmental studies on proteins from haemolymph, fat body and ovary of a phytophagous, bug *Dysdercus koenigii* (Heteroptera: Pyrrhocoridae), *Biochem. Arch.* **10(4)**: 297–302.

Ward, K. E. and Landolt, P. J. (1995) Influence of multiple matings on fecundity and longevity of female cabbage looper moths (Lepidoptera: Noctuidae), *Ann. Entomol. Soc. Am.* **88**: 768–772.

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A New Species of Thrips of the Genus *Leeuwenia* Karny (Phlaeothripidae: Thysanoptera) from Manipur

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ABSTRACT: The description of *Leeuwenia ananthakrishnani* sp. nov. has been provided along with a key to the Indian species of *Leeuwenia*.

KEYWORDS: Thrips, *Leeuwenia ananthakrishnani*, Oak, *Quercus* sp.

INTRODUCTION

The genus *Leeuwenia* is characterised by an exceptionally long and pilose tube, reticulate body, broad rounded mouth cone, a distinct notch behind eyes, cheeks with spines, head broad at base slightly converge at front and narrow across eyes (Ananthakrishnan, 1964, 1970). In India, this genus is represented by five species namely *Leeuwenia coriacea* (Bagnall), *L. eugeniae* Bagnall, *L. karnyiana* Priesner, *L. maculans* Priesner & Seshadri and *L. vorax* Ananthakrishnan (Ananthakrishnan and Sen, 1980). Among them, the occurrence of the commonest species *L. karnyiana* (= *L. ramakrishnae*) and *L. maculans* has already been reported from north east India (Sen *et al*, 1988; Varatharajan, 1999). During a survey carried out in Manipur, one more species of the genus *Leeuwenia* has been collected from oak plant. This paper gives an account of *L. ananthakrishnani* sp. nov. from Manipur.

***Leeuwenia ananthakrishnani* sp. nov. (Fig. 1)**

Macropterous female

Body blackish brown; proximal half all femora and tibiae greyish and distally brown; antennal segments 1, 2, 7, 8 dark shaded and on 3, 4, 5, 6 the proximal 1/4, 1/3, 2/3 and 3/4 shaded. Head longer than wide, with a clear notch behind eyes. Cheeks wide

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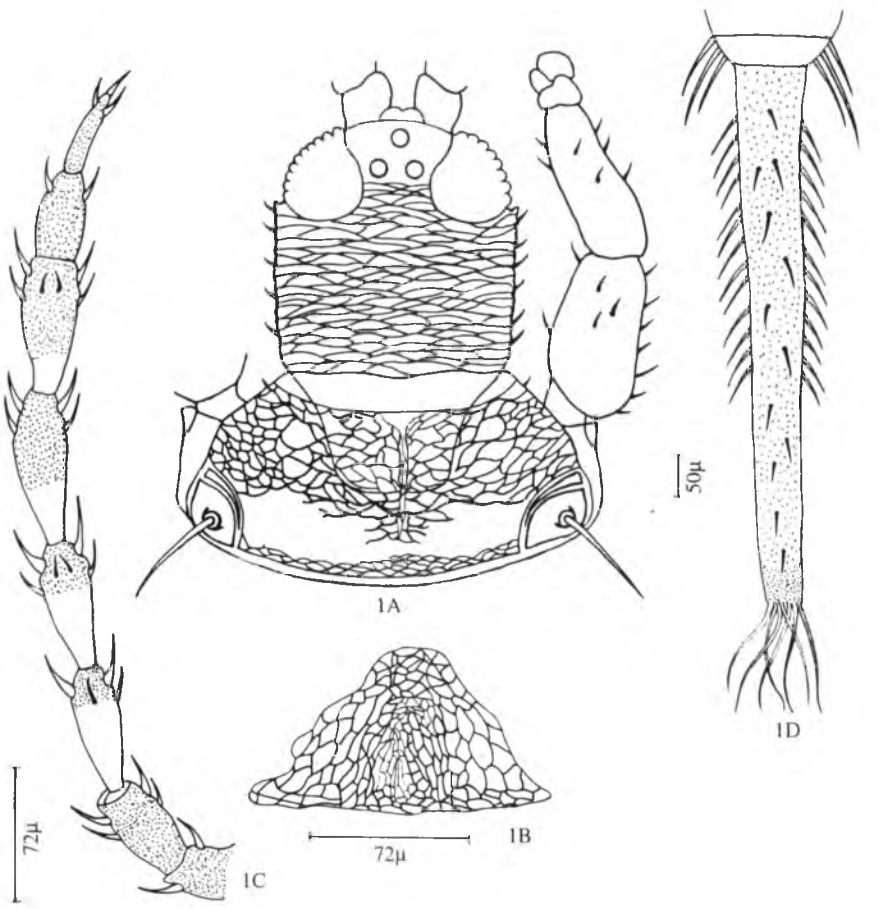

FIGURE 1. (A) Head and pronotum; (B) Pelta; (C) Antenna; (D) Tube.

behind eyes with few short spines. Anteroangulars very short; mid laterals absent. Body with distinctly large meso and metathorax and gradually tapering abdomen. Pelta pyramid shaped. Tube gradually tapers from the base (80 : 65 : 50) to apex and 2.2–2.9 times longer than head and 8–9 times longer than its greatest width. All setae pale brown; wings faint yellow with a dark median streak and without double fringes.

Head 266–342 long, 190–209 wide across eyes, 199–218 across cheeks and 209–218 at base. Eyes 85–105 long, 50–75 wide; paired ocelli 12–15 wide.

Antennal segments length (width)

I: 25–34 (42–47); II: 47–60 (42); III : 70–92 (25–35); IV: 70–92 (35–38); V: 75–88 (38); VI: 60–88 (30–37); VII: 40–52 (27–32); VIII: 32–42 (15–17).

Antennal sense cones 20–32 long. Mouth cone broad, 142 long; 140 – 152 wide at base and 95 at apex.

Prothorax 160–180 long, 237–285 wide across anterior margin, 285–399 wide at posterior margin; anteroangulars 8–12 long and epimerals 95–120 long. Pterothorax 389–456 long, 427–475 wide across mesothorax and 475–532 wide across metathorax. Forefemora 162–190 long, 75–90 wide, foretarsi unarmed. Forewings 1058–1104 long, 85 wide at base, 95 at middle and 66 at apex; basal wing setae B1: 40–52, B2: 37–60, B3:50–87 long, and without double fringes.

Abdomen 418–475 wide at base, 389–427 at middle, 342–360 at segment VII, 294–323 at VIII and 152–190 at IX segment; B1, B2 and B3 of segment IX: 75–100; 115–142 and 70–112 long respectively. Tube 674–779 long, 76–92 wide at base, 62–70 at middle, 47–55 wide at apex. Anal setae 112–190 long. (All measurements in μ).

Total body length 2.829 to 3.163 mm.

Holotype ♀, Z.S.I. Reg. No. 4942/H 17, Chandel, Manipur State, 1100 m MSL, Leaves of *Quercus* sp. (Fagaceae), 17.iii.1991, Coll. R. Varatharajan.

Paratype 1 ♀, Z.S.I. Reg. No. 4943/H 17. Rest of the data same as for the holotype.

Etymology The species is named after Professor T.N. Ananthakrishnan, a renowned Indian Entomologist and it is dedicated to him on his 75th birthday.

Remarks The new species *Leeuwenia ananthakrishnani* is similar to *L. karnyiana* (= *L. ramakrishnae*) in the presence of short anteroangular which is absent in all the other known Indian species of *Leeuwenia*. It also shows similarity to *L. maculans* by having a gradual tapering tube (80 : 65 : 50) and the head longer than wide. However, *L. ananthakrishnani* is distinctly different from other known Indian species viz., *L. coriacea*, *L. eugeniae, L. karnyiana, L. maculans* and *L. vorax* by having a short tube, whose length varies from 2.2 to 2.9 times more than head length and 8 to 9 times its greatest width. On the other hand, the tube length in all the other five species mentioned above has been 4 or >4 times that of head length and >14 times its greatest width (Ananthakrishnan and Sen, 1980).

KEY TO THE INDIAN SPECIES OF *LEEUWENIA*

1. Anteroangulars absent.....2
   Tube 5 times more than head length and 18 times to its greatest width at middle. Tube setae moderately long, Anteroangulars present but short (19 μ). Abdomen tapering sharply. Head slightly conical, little produced.
   ..... *karnyiana* Priesner 1929
   Tube 2.2 to 2.9 times more than head length and 8 to 9 times its greatest width. Tube setae not so long. Anteroangular short (8–12 μ). Abdomen tapers gradually. Head (rectangular) longer than wide, cheeks with a few short spines.
   ..... *ananthakrishnani* sp. nov.

2. Tube almost cylindrical long, 4.5 times head length and 23 times its greatest width. Tube setae weak, short adpressed
   ..... *eugeniae.*
   Tube gradually tapering to apex or of equal width at base and middle, never very long and thin as in *eugeniae* 3
3. Tube gradually tapering behind (6 : 5 : 4), 4 times head length and 15.8 times its greatest width. Head much longer than wide and cheeks with numerous spines. *maculans.*
   Head shorter, tube of equal width at base and middle (5 : 5 : 4), tapering at apex, cheeks with a few spines. 4
4. Tube 4 times head length and 14–15 times its greatest width. Head at base more tuberculate than reticulate. Tube setae adpressed, well developed. Epimeral region better specialized. Antennae slender. ..... *vorax* Ananthakrishnan (1970)
   Tube as in *L. vorax*, tube setae weaker. Head at base distinctly reticulate, not tuberculate. Epimeral region less specialized. Antennal segments not slender *coriacea.*

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REFERENCES

Ananthakrishnan, T. N. (1964) A contribution to our knowledge of the Tubulifera (Thysanoptera) from India, *Opusc. Ent. Suppl.* **25**: 57–58.

Ananthakrishnan, T. N. (1970) Studies on the genus *Leeuwenia* Karny, *Oriental insects* **4(1)**: 47–58.

Ananthakrishnan, T. N. and Sen, S. (1980) *Taxonomy of Indian Thysanoptera*, Zoological Survey of India, Handbook series: 234.

Sen, S., Pramanik, N. K. and Sengupta, C. K. (1988) *Thysanoptera fauna of North Eastern India*, Occasional paper No. 100. Zoological Survery of India: Calcutta, 123.

Varatharajan, R. (1999) *Biodiversity of Insects with Special reference to Thrips (Thysanoptera) of Manipur*, Proc. Symp. Biodiversity & Conservation. Shillong: NEHU, 77–80.

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Influence of Juvenile Hormone on the Early Embryonic Development of *Dysdercus cingulatus* Fabr. (Heteroptera: Pyrrhocoridae)

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ABSTRACT: Topical application of Juvenile Hormone analogue (JHa) Methoprene, anti Juvenile hormone agent, Precocene-II and Juvenile Hormone acid (Methoprene acid) on to 0 day, 1 day, and 2 day old eggs of *Dysdercus cingulatus* affected embryonic development. Rate of hatchability in methoprene treated eggs were also low and most of them developed to dwarf embryos. JH-acid treatment stopped egg development at an early stage. Eggs that received precocene failed to develop beyond blastoderm stage. The degree of morphogenetic malformation in the treated eggs was found to be dose dependent. This morphogenetic effect induced by exogenous JH and anti-JH compounds confirm that JH plays a crucial role during early embryonic development in this insect. This further implicate that embryonic development is subject to inhibition by the very same hormonally active material which are effective in blocking metamorphosis.

KEYWORDS: Methoprene, Precocene, JH-acid, Embryonic development, *Dysdercus cingulatus*.

INTRODUCTION

Juvenile hormones (JHs) produced in corpora allata (CA) are one of several important classes of insect hormones which play a key role in insect embryogenesis, molting, metamorphosis and reproduction (Riddiford, 1994; De Kort and Granger, 1996; Wyatt and Davy, 1996; Wyatt, 1997; Gilbert *et al*, 2000). They act as special repressor agents which inhibit morphogenetic process for a determined time at any stage between the fertilized egg cell and fully differentiated adult and is hence responsible for the existence of polymorphic immature stages so characteristic of insect development (Slama, 1972). JH-active matrial has been detected by physico-chemical methods in eggs and embryos of several species of insects (Bergot *et al*, 1981; Baker *et*

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al, 1984; Lanzrein *et al*, 1984, 1985; Temin *et al*, 1986; Rembold *et al*, 1992; Shout and Edwards, 1992). Many compounds posses activities, which interfere with endocrine functions, governed by JH in insects. Exogenous JH and anti-JH blocks embryonic development of insects in many Orders including Anoplura (Vinson and Williams, 1967), Coleoptera (Walker and Bowers, 1970), Hemiptera (Matolin, 1970), Homoptera (Staal, 1972), Hymenoptera (Troisi and Riddiford, 1974), Lepidoptera (Riddiford, 1972), Orthoptera (Novak, 1969) and Thysanura (Rodendorf and Sehnal, 1973). Studies have found that JH mimics and anti-JHs when applied to eggs at varying times during embryogenesis can block the egg-larval transformation and metamorphosis (Slama and Williams, 1966; Novak, 1969; Smith and Arking, 1975; Dorn, 1982; Hoffmann and Lagueux, 1985; Bruning and Lanzrein, 1987; Burgin and Lanzrein, 1988; Roe *et al*, 1987; Kumaran, 1990; Jacob, 1995; Truman and Riddiford, 1999).

Juvenile hormone can thus act as an ovicide when given to adult females or to her freshly laid eggs. This ovicidal property appears to be one of the most promising means of insect control by JH. The present study examines the effects elicited by these compounds onto the eggs and compares activities of substances representing various chemical classes of hormonally active agents.

MATERIAL AND METHODS

Insects

The insect used in this study *Dysdercus cingulatus* (Heteroptera:Pyrrhocoridae) adults were reared in our laboratory under controlled conditions (temp: 28 ± 31 °C, L/D cycle 12:12 and rh 90 ± 3) and fed on soaked cotton seeds. Eggs were laid in clusters between cottonseeds and were collected at various intervals, so that known age of eggs were available which was used for the present study.

Hormonally active compounds

Juvenile Hormone analogue (Methoprene) and Methoprene acid were gift from Prof. Govindan Bhaskaren, Texas A&M University, USA. Anti-Juvenile Hormone agent, Precocene II (6–7-methoxy-2, 2-dimethyl, 3-chromene) was procured from Sigma St.Louis, USA.

Topical application

Methoprene, Methoprene acid Precocene II were diluted in acetone. Various concentrations of 1 μg, 0.5 μg, 0.25 μg and 0.125 μg/egg in 1 μl of acetone was topically applied on to the dorsal surface to 0 day, 1 day, and 2 day old eggs of *D. cingulatus* in droplets dispensed from a Hamilton repeater syringe.

Whole mount preparation

Eggs were fixed in Carnoy's fluid for 1–2 hours that were punctured with a file needle. These eggs were transferred to 80% ethanol, removed chorion, hydrated, washed in

TABLE 1. Influence of Methoprene on embryonic development of *D. cingulatus.*

Age of eggs	Dosage/egg	Results
0-day old	1 μg 0.5 μg 0.25 μg 0.125 μg	Embryonic development arrested at dorsal closure stage
1-day old	1 μg 0.5 μg 0.25 μg 0.125 μg	Embryos almost completed development
2-day old	1 μg 0.5 μg 0.25 μg 0.125 μg	Embryos completed development but were unable to hatch. Dwarf embryos were also present.

distilled water and placed in cold 1 N HCL for ten minutes each. Then they were washed in distilled water to remove traces of HCL and kept in Schiff's reagent till a reddish purple colour develops on embryos. The eggs were dehydrated and cleared over night in cedar wood oil and mounted in DPX.

RESULTS

The eggs of *D. cingulatus* are elliptical, creamy white in colour with a thick chorion. Creamy white colour changes to yellow on early fourth day and to orange red on fifth day or on early sixth day. Control eggs that received only acetone hatched normally on to 1st instar nymph on fifth or on early sixth day. Application of JHa, JH acid and anti-JH all elicited a great variety of morphogenetic effects on embryos.

It was found that the juvenilising morphogenetic changes increased with time after the beginning of morphogenesis. The degrees of morphogenetic malformation in the recipient eggs were found to be both dose- and age- dependent. Eggs just after oviposition were sensitive to JH analogue, anti JH, and JH acid.

Embryonic development in methoprene treated eggs stopped at dorsal closure or at blastokinesis stage thus preventing hatching. Embryos without dorsal closure, dwarf embryos, embryos which completed their development but were unable to hatch and embryos died while hatching were observed (Table 1).

When Methoprene was given in low doses (0.125 μg *and* 0.25$\mu g/\mu l$) to early eggs these developed to dwarf embryos, while eggs treated with high dosage, (0.5 μg *and* 1 μg) embryonic development continued up to dorsal closure stage. However 1 day and 2 day old eggs were not very sensitive to these treatments (Fig. 1). Low doses to later stage eggs showed embryos which completed their development but unable to hatch. Embryos with out dorsal closure were found when late stage eggs received 0.5 μg *and* 1 μg of methoprene (Table 1).

TABLE 2. Effect of precocene of eggs of *D. cingulatus.*

Age of egg	Dose/egg	Results
0-day	1 μg	
	0.5 μg	
	0.25 μg	
	0.125 μg	
1-day	1 μg	Irrespective of dosage and age all eggs
	0.5 μg	stopped development at varying stages
	0.25 μg	from cleavage to blastoderm
	0.125 μg	
2-day	1 μg	
	0.5 μg	
	0.25 μg	
	0.125 μg	

TABLE 3. Development of *D. cingulatus.* eggs treated with Methoprene acid.

Age of egg	Dosage/egg	Results
0-day	1 μg	Development stopped at later stages of
	0.5 μg	blastoderm formation and early
	0.25 μg	stages of germband formation
	0.125 μg	
1-day	1 μg	Germband formation started
	0.5 μg	
	0.25 μg	
	0.125 μg	
2-day	1 μg	Well developed germband
	0.5 μg	
	0.25 μg	
	0.125 μg	

In Precocene - treated eggs, embryos did not develop beyond blastoderm formation irrespective of age and dosage, (Table 2 and Fig. 2). while eggs which received JH-acid stopped embryonic development at an early stage before germband formation and segmentation (Table. 3). Here high dosage of JH acid or when the recipient eggs were in early stages then development stopped at germband formation (Fig. 3 and Fig. 4).

DISCUSSION

The present study has documented the ability of Juvenile hormone analogue and anti JH compounds to block the embryonic development of *D. cingulatus.* The effects are maximal when the compounds were used in high concentrations and is brought

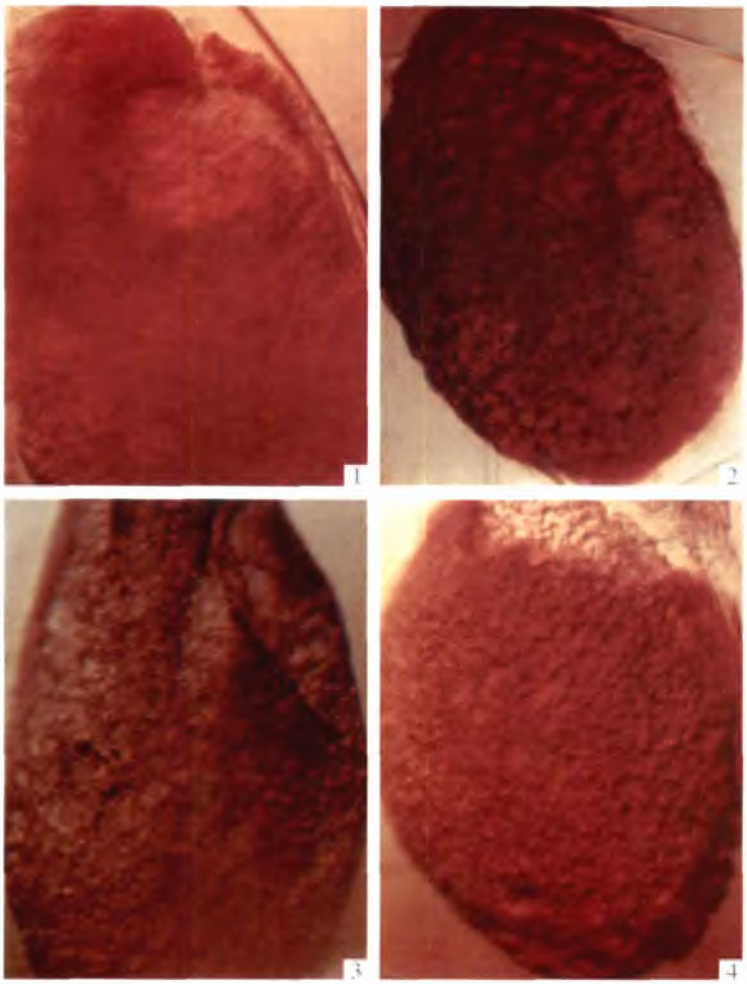

FIGURE 1. 1-day old egg treated with 0.5 μg methoprene.

FIGURE 2. 1μg precocene when given to 0-day old egg.

FIGURE 3. 0-day old egg which received 0.5μg methoprene acid.

FIGURE 4. 1-day old egg treated with 0.25μg methoprene acid.

into contact with the eggs very early. It appears that the absence of JH, early in embryogenesis is critical to normal development and hatching. Juvenoid treatment of newly oviposited eggs blocked devlopment shortly after germband formation. These results were duplicated in several insect species earlier (Slama and Williams, 1966; Riddiford and Williams, 1967; Novak, 1969; Riddiford, 1970; Matolin, 1970; Hunt and Shappiro, 1973; Rodendorf and Sehnal, 1973; Smith and Arking, 1975; Injeyan

et al, 1979; Jacob, 1983; Hoffmann and Lagueux, 1985; Hardlie, 1987; Jacob and Prabu, 1988; Ishaaya and Horowitz, 1992; Jacob, 1995).

Studies on the effect of exogenous JH in *D. cingulatus* embryos of diverse ages show that the presence of this hormone in early stages of embryogenesis (cleavage, blastoderm formatiom and grastrulation) is deleterious to normal development. Depending on dosage and time of JH application, embryonic development is blocked either at germband stage, or at blastokinesis stage. Delayed effects are also seen. Novak (1969) confirmed that in hemimetabolus insects, JH free period is essential for normal embryogenesis by treating with JHa.

Failure of the JH- treated embryos to develop beyond blastoderm or germband stage in the present study appears to be directly related to JH's hormonal effect rather than the result of a non-specific pharmacological effect since eggs of *D. cingulatus* display characteristic difference on life stage and dose response results of developmental arrest. Inhibitory effect of JH has been interpreted as levels of differentiation process (Novak, 1967) possibly resulting from JH blocking transcription (Williams and Kafatos, 1971). The morphogenetic defects in dorsal closure, blastokinesis and shortened appendages all may be consequences of inhibition of cell division and or cell orientation.

Embryonic morphogenesis can thus be arrested at any stage by the additional supply of JH. Afterwards, development can continue under different conditions, when the substances ceases to act. Any structure characteristic of embryonic development, starting with cleavage cells, can thus be kept alive for a period equal to the hatching time of the control embryos. In addition, a wide range of new, abnormal structures can appear, either as a result of heterochronia or of direct morphogenetic action (Novak, 1966).

Miniature embryos appeared after the application of smaller amounts of JHa to freshly laid eggs. Its effect thus seems to consist in causing the survival and further growth of that part of embryonic blastoderm which normally die and disintegrate during germinal band formation. If the substance starts to act after germband differentiation then it cannot arrest embryonic development since during germband formation, the eggs becomes progressively less sensitive (Novak, 1990). Then if differentiation is not completed, the structure of the undifferentiated cells is preserved, and isometric growth of both the germband and the surrounding undifferentiated blastoderm cells continue (Novak, 1990).

However, situation in early embryos is quite different because of an unlimited food supply in the form of yolk mass. If the applied substance is sufficiently large, this state may continue unless reserved substance in the yolk are consumed. when only a small dose has been applied, the substance stops to act for a period of and afterwards growth and morphogenesis are resumed (Novak, 1966). This would adequately explain why further differentiation of the germinal band is not stopped unless the effect of the JHa is strong or persistent.

As is evident from the present studies, JHa applied to the late embryos in low doses blocks development at the embryonic—larval transition stage. Once the

egg starts embryogenesis, JHa can no longer block development at the germband, but only later at embryonic—larval transition stage. Thus it blocks the hatching of fully differentiated embryos. These effects of JH deprivation on the late half of embryogenesis can be explained on the basis of JH effects on metamorphosis by Kumaran (1990) who suggested that exogenous JH might interrupt embryonic development by supression of DNA synthesis and cell division.

In several insect species, JH—specific esterase, JHE that actively appears around blastokinesis is maintained at relatively low levels through hatching and during this developmental stage, the JH titer is high. High JHE activity during early embryogenesis play a functional role in maintaining low JH titers, which is necessary for normal development (Roe and Venkatesh, 1990).

It is evident from studies by Bergot *et al* (1980, 1981) that JH activity is lowest during early embryogenesis and increased after dorsal closure. Changes in JH titer occured prior to egg- embryo transformation i.e., before blastoderm is formed. This peak in JH titer is concurrent with the programming of the CA development in embryo. One possibility in the defects occurred after the administration of JHa is that exposure of the *D. cingulatus* egg to JH must have interfered with the programming of the CA for the cessation of JH secretion which must take place before metamorphosis as in the case of *Oncopeltus fasciatus* (Dorn *et al*, 1987).

Physiological JH titer is essential for normal development beyond the germband stage. Application of allatotoxin, Precocene II, on early embryos of *D. cingulatus* stopped development after blastoderm stage was observed in this study. Dorn (1982) showed precocene treatment on freshly laid eggs of *O.fasciatus* resulted in a defect in dorsal closure. This could be the triggering effect of absence of JH after dorsal closure, when the CA becomes active and the JH titer increases resulting in the delay in normal development (Bruning *et al*, 1985; Bruning and Lanzrein, 1987). When embryos after dorsal closure was treated with Precocene, Bruning and Lanzrein (1987) observed delay in development, malformation, and lack of larval characteristics in *Nauphoeta cinerea*. This suggests that JH play a role in late embryogenesis. JH has an important role in embryonic morphogenesis at germband formation or at blastokinesis. Application of methoprene acid thus confirms the view that JH is necessary in later part of embryogenisis before hatching.

Embryonic development can be thought of as a progressive utilization of genetic information. In the insect embryo, the two major critical steps are the switching - on of the zygotic genome at blastoderm formation, then of the larval genome at blastokinesis. Application of exogenous JH to early eggs blocks the first step—the activation of the zygotic genome. When JHa is applied after germband formation i.e., after the turning on of the embryonic genome, it has progressively less effect on embryonic development. This delayed action on the developing corpus allatum, and hence its secretion does not ebb and flow in the normal manner. Anti-JH and JH acid can block development by altering JH titer in the egg showing anti allatal effect.

Normally JH levels declined through early development, increased during dorsal closure and declined again as hatching approached. The age and dose- dependent ef-

fects of Juvenile hormone analogue and /or anti allatal compounds on embryogenesis indicate a biological role for Juvenile hormone in embryonic development.

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REFERENCES

Baker, F. C., Lanzrein, B, Miller, C. A., Tsai, L. W., Jamieson, G. G and Schooley, D. A. (1984) Detection of only **JH III** in several life stages of *Nauphoeta cinerea* and *Thermobia domestica*, *Life Sci.* **35**: 1553–1560.

Bergot, J. B., Jamieson, G. C., Ratcliff, M. A. and Schooley, D. A. (1980) JH Zero: new naturally occurring Juvenile hormones from developing embryos of the tobacco horn Worm, *Science* **210**: 336–338.

Bergot, J. B., Baker, F. C., Cerf, D. A. and Shooley, D. (1981) Qualitative and quantitative aspects of Juvenile hormone titer in developing embryos of several inspect species, discovery of a new JH like substance extracted from eggs of *Manduca Sexta*, In: *Juvenile Hormone Biochemistry*, developments in Endocrinology. Pratt, G. E. and Brooks, G. T.: (Editors). Elsevier/ North Holland Biomedical press: Oxford, **15**: 33–45.

Bruning, E. and Lanzrein, B. (1987) Function of Juvenile hormone III in embryonic development of the Cockroach, *Nauphoeta cinerea*, *Int. Invert. Reprod. Dev.* **12**: 29–44.

Bruning, E., Saxer, A. and Lanzrein, B. (1985) Methylfarnosoate and Juvenile hormone III in embryonic development of the cockroach, *Nauphoeta cinerea*, *Int. Invert. Reprod. Dev.* **12**: 29–44.

Burgin, C. and Lanzrein, B. (1988) State–dependent biosynthesis of methyfarnesoate and metabolism of Juvenile hormone III in embryos of the cockroach *Nauphoeta cinerea*, *Insect Biochem.* **18**: 3–9.

Dorn, A. (1975) Structural and function of the embryonic corpus allatum of *Oncopeltus Fasciatus*, Dallas (Insecta:Heteroptera), *Cytobiologia* **10**: 235–248.

Dorn, A. (1982) Precocene-induced effects and possible roles of Juvenile Hormone during embryogenisis of the milkweed bug *Oncopeltus fasciatus*, *Gen. Comp. Endocr.* **46**: 42–52.

Dorn, A., Bishoff, S. T. and Gilbert, L. I. (1987) An incremental analysis of the embryonic development of the tobacco hornworm, *Manduca sexta*, *Int. J. Invert. Reprod. Dev.* **11**: 137–157.

Gilbert, L. I., Granger, N. A. and Roe, R. M. (2000) The JH: Historical facts and speculations on future research directions, *Insect Biochem. Mol. Biol.* **30**: 617–644.

Hoffmann, J. A. and Lagueux, M. (1985) Endocrine aspects of embryonic development in Insects, In: *Comprehensive Insect Physiology, Biochemistry and Pharmacology*, Gilbert, L. I. and Kercut, G. A.: (Editors). Pergamon press: New york, **I**: 435–460.

Hunt, L. M. and Shappiro, D. G. (1973) Larval development *following Juvenile hormone* analogue treatment of eggs of the lesser milkweed bug, *Lygaeus kalmii*, *J. Insect. Physiol.* **19**: 2129–2134.

Injeyan, H. S., Tobe, S. S. and Rapport, E. (1979) The effects of exogenous Juvenile hormone treatment of embryogenisis is *Schisticercca gregaria*, *Can. J. Zool.* **57**: 838–845.

Ishaaya, I. and Horowitz, A. R. (1992) Novel Phenoxy Juvenile hormone analogue (Pyriproxyfer) suppresses embrogenisis and adult emergence of sweet potato white fly (Homoptera:Aleyrodidae), *J. Econ. Entomol.* **85**: 2113–2118.

Jacob, M. (1983) Influence of topically applied Juvenile hormone analogues on the embryonic development of *Dysdercus cingulatus* (Pyrrhocoridae:Heteroptera), Ph.D. Thesis, Department of Zoology, University of Kerala, Trivandrum.

Jacob, M. (1995) *Endocrines in Insect Embryonic Development. In Recent Advances in Insect Endocrine Research*, Muraleedharen, D. and Mariamma, Jacob: (Editors). Association for advancement of Entomology: Trivandrum.

Jacob, M. and Prabhu, V. K. K. (1988) Effects of two Juvenile hormone analogues on Embryonic morphogenesis, histogenesis, endocrines and cuticulogenesis of *Dysdercus cingulatus* (Heteroptera:Pyrrhocoridae), *Acad. Sci.* **97**: 55–65.

De Kort, C. A. and Granger, N. A. (1996) Regulation of JH titers: The relevance of degradative enzymes and binding proteins, *Arch. Insect Biochem. Physiol.* **33**: 1–26.

Kumaran, A. K. (1990) Modes of Action of Juvenile Hormone at Cellular and Molecular Levels, In: *Morphogenetic Hormones of Arthropods*, Vol. I. Gupta, A. P.: (Editor). Rutgers Univ. press: New Jersey, 197–198.

Lanzrein, B., Gentinetta, V., Abegglen, H., Baker, F. C., Miller, C. A. and Schooley, D. A. (1985) titers of ecdysone, 20-hydroxy ecdysone and Juvenile hormone III throught out the life cycle of a hemimetabolus insect, *Nauphoeta cinera*, *Experientia* **4**: 913–917.

Lanzrein, B, Imboden, H, Burgin, C, Bruning, E and Gzeller, H (1984) On titers, origin and functions of Juvenile hormone III, methyl farnesoate and ecdysteriods in embryonic development of the ovoviparous cockrach *Nauphoeta cinera*, In: *Biosynthesis, Metabolism and Mode of Action of Invertebrate Hormones*, Hoffmann, J. and Porchet, M.: (Editors). Springer-Verlag: Berlin.

Matolin, S. (1970) Effects of a Juvenile hormone analogue on embryogenisis in *Pyrrhocoris apterus*. L., *Acta Ent. Bohemoslov* **67**: 9–12.

Novak, V. J. A. (1966) Insect hormones. London Methuen..

Novak, V. J. A. (1967) The Juvenile hormone and the problem of animal morphogenisis, In: *Insects and Physiology*, Oliver & Boyd: Edinburgh and London.

Novak, V. J. A. (1969) Morphological analysis of the effects of Juvenile Hormone analogues and other morphologically active substances of embryos of *Schistocerca gregaria* Forskal, *J. Embryol. Exp. Morphol.* **21**: 1–21.

Novak, V. J. A. (1990) Role of gradient factor in Arthropod morphogenesis, In: *Morphogenetic Hormones of Arthropods. Roles in Historganogenesis and Morphogenesis*, Vol. III. Gupta, A. P.: (Editor). Rutgers Univ. press: New Jersey, 3–44.

Rembold, H., Czoppelt, C. H., Grune, M., Lackner, B., Pfeffer, J. and Worker, E. (1992) Juvenile Hormone titers during Honey bee embryogenesis and metamorphosis, In: *Insect Juvenile Hormone Research, Fundamental and Applied Approaches Chemistry, Biochemistry and Mode of Action*, Mauchamp, B., Couillaud, F. and Baehr, F. C.: (Editors). INRA: Paris.

Riddiford, M. (1970) Prevention of metamorphosis by exposure of insect eggs to Juvenile Hormone analogues, *Science* **167**: 287–288.

Riddiford, L. M. (1972) Juvenile Hormone and insect embryonic development: Its potential role as on oviside, In: *Insect Juvenile Hormone Chemistry and Action*, Menn, J. J. and Beroza,: (Editors). Academic Press: Orlando, Florida, 95–111.

Riddiford, L. M. (1994) Cellular and molecular actions of Juvenile Hormone. I. general Considerations and premetamorphic actions, *Adv. Insect Physiol.* **24**: 213–274.

Riddiford, L. M. and Williams, C. M. (1967) The effect of Juvenile Hormone analogues on the embryonic development of silkworks, *Proc. Natl Acad. Sci.* USA **57**: 595–600.

Roe, R. M. and Venkatesh, K. (1990) Metabolism of Juvenile hormones: degradation and titer regulation, In: *Morphogenetic Hormones of Arthropods*, Vol. I. Gupta, A. P.: (Editor). Rutgers Univ. Press: London, 125–181.

Roe, R. M., Crawford, C. L., Clifford, C. W., Woodring, J. A., Sparks, T. C. and Hammock, B. D. (1987) Role of Juvenile Hormone metabolism during embryogenesis of the House Cricket, *Acheta domesticus*, *Insect Biochem.* **17**: 1023–1026.

Rodendorf, E. B. and Sehnal, F. (1983) Juvenile Hormone analogue, In: *Endocrinology of Insects*, Alan. R. Liss. Inc.: New York, 657–672.

Shout, J. E. and Edwards, J. P. (1992) Levels of Juvenile Hormone III in the oriental Cockroach *Blatta orientalis* (L) (Dictyoptera: Blattidae), In: *Insect Juvenile Hormone Research, Fundamental and Applied Approaches. Chemistry, Biomistry and Mode of Action*, Mauchamp, B., Couillaud, F. and Baehr, F. C.: (Editors). INRA: Paris.

Slama, K. (1971) Insect Juvenile hormone analogues, *Rev. Biochem.* **40**: 1079–1102.

Slama, K. and Williams, C. M. (1966) Paper factor as an inhibitor of the embryonic development of the European bug *Pyrrhocoris apterus*, *Nature* **210**: 329–330.

Smith, R. F. and Arking, R. (1975) The effects of Juvenile hormones analogues on the embrogenesis of *Drosophila melanogaster*, *J. Insect Physiol.* **21**: 723–732.

Staal, G. B. (1972) Biological activity and bioassay of Juvenile Hormone analogues, In: *Insect Juvenile Hormone Chemistry and Action*, Menn, J. and Beroza, M.: (Editors). Academic Press: New York, 69–94.

Temin, G., Zander, M. and Roussel, J. P. (1986) Physico–Chemical (GC–MS) measurement of Juvenile Hormone III titers during embryogenesis of *Locusta migratoria*, *Int. J. Invert. Reprod. Dev.* **9**: 105–112.

Troisi, S. J. and Riddiford, L. M. (1974) Juvenile Hormone effects on metamorphosis and reproduction of the Fire ant, *Solenopsis invicta*, *Environ. Ent.* **3**: 112–116.

Truman, J. W. and Riddiford, L. M. (1999) The origins of insect metamorphosis, *Nature* **401**: 447–452.

Vinson, J. W. and Williams, C. M. (1967) Lethal effects of synthetic Juvenile hormone on the human body louse, *Proc. Natl Acad. Sci.* USA **58**: 294–297.

Walker, W. F. and Bowers, W. S. (1970) Synthetic Juvenile hormones as potential Coleopteran ovicides, *J. Econ. Ent.* **63**: 1231–1233.

Williams, C. M. and Kafatos, F. C. (1971) Theoretical aspects of the action of Juvenile hormone, *Mitt. Schweiz. Entomol. GES.* **44**: 151–162.

Wyatt, G. R. (1997) Juvenile hormone in insect reproduction–a paradox, *Eur. J. Entomol.* **94**: 323–333.

Wyatt, G. R. and Davy, K. G. (1996) Cellular and molecular actions of Juvenile hormone III roles of Juvenile hormone in adult insects, *Adv. Insect Physiol.* **26**: 1–155.

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New report on some crab spiders (Araneae: Thomisidae) from Kerala, India

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ABSTRACT: Crab spider belonging to tow genera and three species were recorded; *Misumena mridulai*, *Thomisus cherapunjeus*, *Thomisus lobosus*.

KEYWORDS: *Misumena mridulai, Thomisus cherapunjeus, Thomisus lobosus*, Thomisidae.

INTRODUCTION

Crab spiders are one of the most handsome forms of spiders possessing bright and beautiful colours. These spiders look like small crab in their appearance due to the arrangement of their legs. Most of the legs of these spiders move sidewise like those of a crab, and the common name for these spiders is crab spiders. Except *Amyciaea forticeps* (Cambr.) (Mathew, 1954) the family Thomisidae has not been recorded so far from Kerala. A short report of the three species of crab spiders along with their diagrams is provided in the present paper. The spiders were collected during the course of research work about the diversity of spiders in Ernakulam district in Kerala.

METHODOLOGY

Ernakulam district is characterized by dense tropical evergreen forest in the eastern portion and coastal ecosystems in the western portion. Due to its geographical and ecological factors, this area exhibits a rich diversity of flora and fauna. Collection of spiders were done in different areas of Ernakulam district using methods suggested by Subrahmanyam (1968) and Tikader (1975). Spiders were collected by handpicking and also by kerchief method. Some spiders were caught by keeping a jar containing spirit below it and by tapping the spider into it. Collected spiders were preserved in 80% ethyl alcohol, and were studied with the help of stereomicroscope (Leica MS 5). Identification of spiders were done by referring to 'The Fauna of India (Araneae)'

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vol 1 by Tikader (1980). Measurements are taken using an eye piece graticule. All diagramns are redrawn after Tikader.

Systematic Account

***Misumena mridulai* Tikader**

*1962 Misumena mridulai Tikader, J. Linn. Soc. London,**44(300):** 573*
*1980 Misumena mridulai Tikader, Fauna of India (Araneae) **I** p 94–95*

Specimens examined: 1. Female, Cochin, 5.ii.2000, Coll. Sunil Jose. K
2. Females, Parur, 4.i. 2001, Coll. P.A. Sebastian

Cephalothorax: yellowish, longer than wide ; cephalic region slightly elevated. Anterior end more narrower, widest behind the middle. Eyes eight, both rows recurved; anterior row strongly recurved than posterior row. ALE larger than other eyes. Ocular quadrangle longer than wide, narrower at the anterior end; posterior row longer than anterior row. Clypeus height more than AME. Legs longer, slender and clothed with spines and hairs. Leg formula 2143. Sternum heart shaped, yellowish, posteriorly acuminate; covered with minute hairs. Chelicerae moderate.
Abdomen yellowish, broader than long; anterior end overlapping posterior end of Cephalothorax; widest behind the middle. Dorsum provided with longitudnal, broad brownish line mid dorsally; five small sigilla present. Epigyne as in Fig. 1b.

Measurements of leg segments

	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	2.50	0.81	2.10	1.70	1.20	8.31
II	2.60	0.85	2.15	1.80	1.30	8.70
III	1.75	0.65	0.95	0.80	0.60	4.75
IV	2.00	0.70	1.00	0.95	0.75	5.40

Measurements (Type Specimen): Body 6.1 mm long, Carapace 2.4 mm long and 2.4 mm wide; Abdomen 3.9 mm long and 4 mm wide.

Measurements: Body 6.3 mm long, Carapace 2.5 mm long and 2.5 mm wide; Abdomen 4 mm long and 4.1 mm wide.

Natural History: Collected from *Zinnia* flowers ambushing a small bee.

Distribution: Shillong (Tikader, 1962); Cochin.

***Thomisus cherapunjeus* Tikader**

*1966 Thomisus cherapunjeus Tikader, Proc. Indian. Acad. Sci. Bangalore. **64(1)** : 54*
*1980 Thomisus cherapunjeus Tikader, Fauna of India (Araneae) **I** p 54–56*

Specimens examined: 1 Female, Cochin 15.iii.2000, Coll. Sunil Jose. K
1 Female, Kothamangalam, 4.ii.2001, Coll. Sunil Jose. K

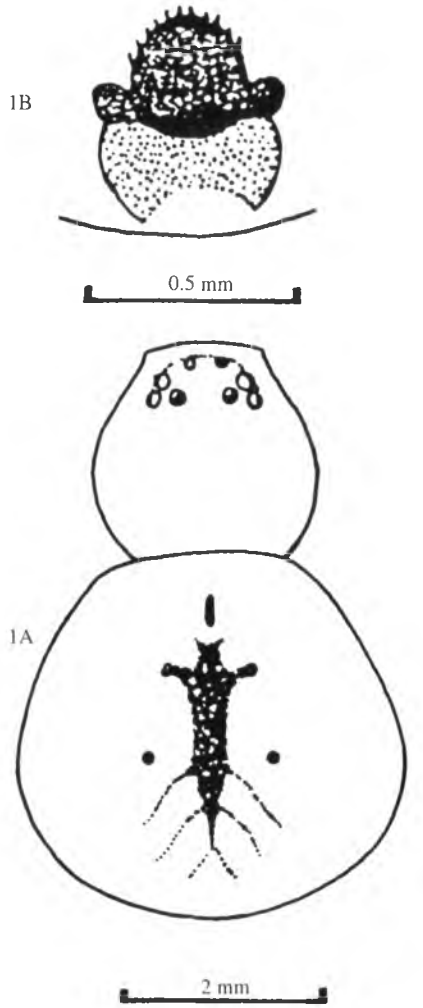

FIGURE 1. *Misumena mridulai* (a) Dorsal view of the female; (b) Epigyne

Cephalothorax: light greenish, longer than wide ; cephalic region elevated and narrowed. A broad deep brown, longitudnal, lateral patch on either side. Ocular tubercle has lateral projections with a chalk white transverse ridge. Dorsum provided with narrow, longitudnal chalk white line mid dorsally. Eyes eight, black in two rows; both rows recurved, posterior row wider than anterior row. ALE larger than AME; MOQ longer than wide, narrow anteriorly. Clypeus moderate. Sternum longer than wide, heart shaped, acuminate posteriorly. Legs longer, stouter and clothed with hairs and spines; anterior legs longer than posterior. Leg formula 2143.

FIGURE 2. *Thomisus cherapunjeus* (a) Dorsal view of the female; (b) Epigyne

Abdomen longer than wide, nearly elliptical in shape, widest behind the middle. Dorsum provided with five sigilla. Three or four longitudnal, deep brown, thin lines present laterally which are confluent at the posterior end. Ventrum pale green with longitudnal muscular elevations. Epigyne as in Fig. 2 b.

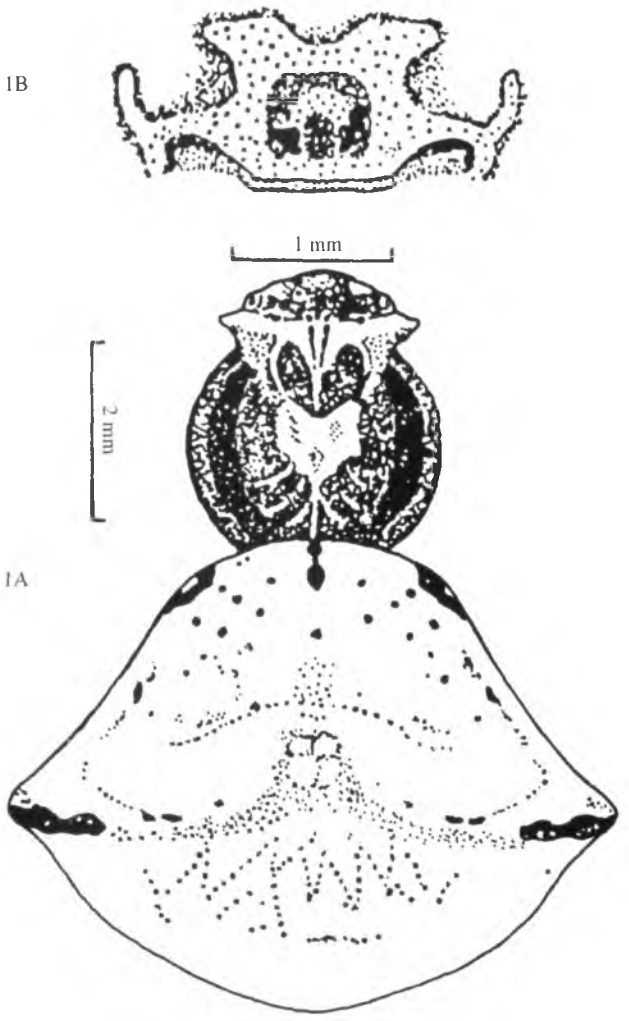

FIGURE 3. *Thomisus lobosus* (a) Dorsal view of the female; (b) Epigyne

Measurements of leg segments

	Femur	Patella	Tibia	Metatarsi	Tarsi	Total
I	3.20	1.10	2.30	1.80	1.40	9.80
II	3.50	1.25	2.55	2.00	1.55	10.85
III	1.92	0.91	1.21	1.00	0.82	5.96
IV	2.41	1.11	1.61	1.21	1.00	7.34

Measurements (Type Specimen): Body 5.2 mm, Carapace 2.2 mm long and 2 mm wide. Abdomen 3.4 mm long and 2.5 mm wide.

Measurements: Body 5.5 mm, Carapace 2.4 mm long and 2 mm wide. Abdomen 3.6 mm long and 2.6 mm wide.

Natural History: Collected from garden flowers hiding under petals.

Distribution: INDIA : Shillong (Tikader, 1966); Cochin.

***Thomisus lobosus* Tikader**

1965 Thomisus lobosus Tikader, Proc. Indian. Acad. Sci. Bangalore ,61(5); 285
1980 Thomisus lobosus Tikader, Fauna of India (Araneae) Vol I p 36–37

Specimens examined: 1 Female, Cochin 3.iii.2000, Coll. Sunil Jose. K
1 Female, Aluva 4.ii.2001, Coll. P.A. Sebastian

Cephalothorax: Longer than wide, brownish; a longitudnal dark brown patch laterally on either side. Mid dorsal region bears a 'v' shaped white conspicuous marking. Eyes eight, in two rows; both rows recurved; Ocular quadrangle longer than wide. Eyes small, round and black; a transverse yellow line between lateral eyes. Clypeus broad. Sternum heart shaped, having a black dot anteriorly. Legs longer, stronger and stout; anterior legs longer than posterior. Leg formula 2143

Abdomen white, wider than long, anterior end protruding over posterior end of Cephalothorax; broadest behind the middle. Dorsum decorated with black spots; lateral protrusion bears black patches laterally. Ventrum pale white. Epigyne as in Fig. 3b.

Measurements of leg segments

	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
I	3.81	1.00	2.80	2.10	1.65	11.36
II	4.00	1.10	3.00	2.00	1.70	11.85
III	2.15	0.90	1.25	1.10	0.90	6.65
IV	2.65	1.00	1.75	1.35	1.20	7.95

Measurements (Type Specimen): Body 8.5 mm, Carapace 3.5 mm long and 3 mm wide. Abdomen 5.5 mm long and 7 mm wide.

Measurements: Body 8.1 mm, Carapace 3.3 mm long and 3 mm wide. Abdomen 5.2 mm long and 7 mm wide.

Natural History: Collected from *Canna* flowers hiding among petals

Distribution: INDIA : Poona (Tikader, 1965); Cochin.

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REFERENCES

Mathew, A. P. (1954) Habits of two spider mimics of red ant, *J. Bom. Nat. Hist. Soc.* **52**: 249–263.

Subrahmanyam, T. V. (1968) An introduction to the study of Indian spiders, *J. Bom. Nat. Hist. Soc.* **65(2)**: 453–461.

Tikader, B. K. (1962) Studies on some Indian spiders (Araneae: Arachnida), *J. Linn. Soc. London.* **44(300)**: 561–584.

Tikader, B. K. (1965) On some new species of spiders of the family Thomisidae from India, *Proc. Indian Acad. Sci. Bangalore* **61(5)**: 277–289.

Tikader, B. K. (1966) Studies on some crab spiders (Family : Thomisidae) from Khasi and Jaintia Hills, Assam, India, *Proc. Indian. Acad.Sci. Bangalore* **64(1)**: 53–61.

Tikader, B. K. (1971) Revision of Indian Crab spiders, *Memoirs Zool. Surv. Ind.* **XV** No: 3: 1–90.

Tikader, B. K. (1975) Key to Indian spiders, *J. Bom. Nat. Hist. Soc.* **73**: 356–370.

Tikader, B. K. (1980) Fauna of India (Araneae) **I** Thomisidae, 1–244.

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Short Communication No. ent.2621

Description of a New Species of *Dialeurolonga* Dozier (Hemiptera: Aleyrodidae) Breeding on *Polyalthia longifolia* Hook with a Key to Indian Species

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ABSTRACT: A new species of the whitefly genus *Dialeurlonga* Dozier viz., *D. malleshwaremensis* from *Polyalthia longifolia* is described and illustrated. A key to Indian species of the genus *Dialurolonga* has been provided.

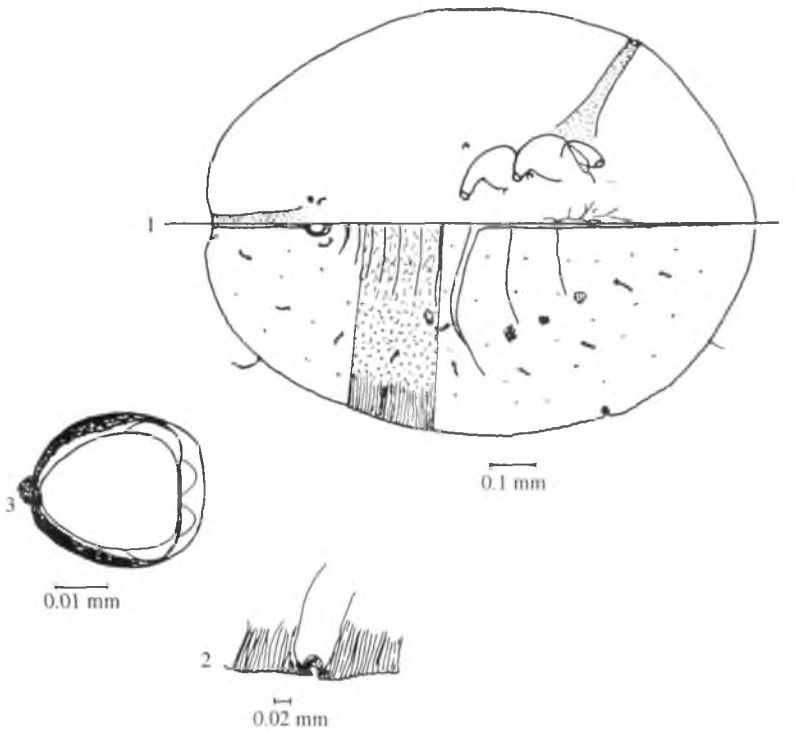
KEYWORDS: *Dialeurolonga malleshwaremensis*, *Polyalthia longifolia*.

Aleyrodids are small inconspicuous phytophagous insects, which are commonly known as whiteflies. Among the various genera of the family Aleyrodidae the genus *Dialeurolonga* was erected by Dozier (1928) as a subgenus under the genus *Dialeurodes* Cockerell. Takahashi (1951) elevated the subgenus *Dialeurolonga* to generic level. This genus is represented in India by three species viz., *D. elongata* (Dozier) on *Citrus* sp., *Ixora coccinea, I. parvifloria, Litchi chinensis* Singh (1931) and *Murraya exotica*David and Subramaniam (1976); *D. maculata* (Singh) on *Ficus religiosa* (Singh, 1931) and *D. lagerstroemiae* Jesudasan and David on *Lagerstroemia speciosa* Jesudasan and David (1991). In the present study one new species breeding on *Polyalthia longifolia* an important avenue tree of India is described in detail. In addition a workable key to Indian species of *Dialeurolonga* is given.

***Dialeurolonga malleshwaramensis* sp.nov.**

Pupal case

White, without secretion of wax; oval, broadest at metathoracic segment region, 1.34–1.66 mm long and 1.04–1.28 mm wide; found singly, one to four per leaf, only on the upper surface of leaves.



FIGURES 1–3: (1) Pupal case; (2) Thoracic tracheal pore; (3) Vasiform orifice.

Margin

Smoothly crenulate, 8–10 crenulations in 0.1 mm; anterior and posterior marginal setae 16 μm and 30 μm long respectively. Thoracic and caudal tracheal pores with invaginations at the margin distinct.

Dorsal surface

Four pairs of blunt dorsal setae–cephalic setae 25 μm long, first abdominal setae 10 μm long, eighth abdominal setae 15 μm and submarginal caudal setae 10 μm long. Submargin with striations, not separated from dorsal disc; subdorsam with irregular shaped microtubercles and submedian area faintly tessellated. Rows of pores and porettes on dorsum distinct. Cephalothorax, with three pairs of submedian tubercles – one pair each on pro, meso and metathoprax and a pair of submedian tubercle on the second abdominal segment. Abdominal segments 2–6 with faint depressions; subdorsam with eight pairs of blunt setae, 10 μm long–five on abdomen and three on cephalothorax evident.

Vasiform orifice cordate, with notch at the caudal end, longer than wide, 70–78 μm long and 62–70 μm wide, with ridges on its inner lateral and posterior side; operculum

subcordate, 50–58 μm long and 48–56 μm wide, filling the orifice, lingula tip partly exposed and knobbed. Thoracic and caudal tracheal furrows distinct, caudal tracheal furrow cylindrical shaped 260 μm long and 8 μm wide.

Ventral surface

A pair of blunt ventral abdominal setae laterad of vasiform orifice 10 μm long and 230 μm apart. Thoracic and caudal tracheal folds distinct with stipples.

Host

Polyalthia longifolia Hook

Specimens examined: Holotype

One pupal case on slide, India, Karnataka; Bangalore; Malleshwaram, *Polyalthia longifolia*, 7. VII. 1999. Coll. R.Sundararaj deposited in the collection of National Pusa Collection, Indian Agricultural Research Institute, New Delhi, India. *Paratypes* seven pupal cases on slides, data as on holotype, to be deposited in the collections of the Systematic Entomology Laboratory, United States Department of Agriculture, Beltsville, Maryland, U.S.A; The Natural History Museum, London, U.K.; and the Zoological Survey of India, Calcutta, India.

This species comes close to *D.strychnosicola Cochi* in shape but differs from it by the presence of submedian tubercles on thoracic segments and second abdominal segment and by the presence of blunt dorsal setae. Also by the pupal cases found only on the upper surface of the leaves.

KEY TO INDIAN SPECIES OF *DIALEUROLONGA* DOZIER

1. Pupal case oval; sub margin without papillae; median pore cephalad of vasiform orifice wanting 2
   Pupal case elongately subelliptical; submargin with a row of conical papillae; cephalad of vasiform orifice a median large pore with a thickly chitinised rim evident ..... *elongata* (Dozier)
2. Margin with less than 20 crenulations in 0.1 mm; thoracic and caudal tracheal pores distinct with invaginations, without internal teeth; dorsum with tubercles or spherical structures 3
   Margin with 27–28 crenulations in 0.1 mm; thoracic and caudal tracheal pores indicated by six minute teeth; dorsum without tubercles or papillae .. *maculata* (Singh)
3. Margin with 16 crenulations in 0.1 mm; cephalic setae and row of subdorsal setae wanting; thoracic and abdominal segments without submedien tubercles but with spherical structures; vasiform orifice as long as wide . *lagerstroemiae* Jesudasan and David.

4. Margin with 8–10 crenulations in 0.1 mm; cephalic setae and a row of subdorsal setae present; thoracic and second abdominal segments with a pair of submedian tubercles; vasiform orifice longer than wide ..... *malleshwaramensis* sp. nov.

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REFERENCES

David, B. V. and Subramaniam, T. R. (1976) Studies on some Indian Aleyrodidae, *Rec.Zool. Surv. India* **70**: 194–195.

Dozier, H. L. (1928) Two new aleyrodid (Citrus) pests from India and the South Pacific, *J.Agric.Res.* **36**: 1001–1002.

Jesudasan, A. R. W. and David, B. V. (1991) Taxonomic studies on Indian Aleyrodidae (Insecta; Homoptera), *Oriental Ins.* **25**: 309.

Singh, K. (1931) A contribution towards our knowledge of the Aleyrodidae (whiteflies) of India, *Mem. Dep. Agric. India* **12(1)**: 89–90.

Takahashi, R. (1951) Some species of Aleyordidae (Homoptera) from Madagascar, with a species from Mauritius, *Mem. Inst. Scient.* Madagascar (A)**6**: 354.

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Short Communication No. ent.26212

Prey preference of a ladybeetle, *Micraspis discolor* (Fabricius)

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ABSTRACT: The experiment was designed to evaluate the prey preference of a ladybeetle, *Micraspis discolor* (Fabricius) amongst nine aphid preys, *viz. Aphis craccivora, Aphis gossypii, Aphis nerii, Brevicoryne brassicae, Lipaphis erysimi, Melanaphis bambusae, Myzus persicae, Rhopalosiphum maidis*, and *Uroleucon compositae*, on the basis of the number of adult aphids consumed by 12 h starved adult female ladybeetle within 24 h. Six replicates of the experiment were designed at $25 \pm 2°C$, $60 \pm 5\%$ R.H. The result revealed that *M. discolor* preferred *A. gossypii* the most and *A. nerii* the least. The order of preference of the ladybeetle was *A. gossypii* > *A. craccivora* > *M. bambusae* > *L. erysimi* > *U. compositae* > *B. brassicae* > *R. maidis* > *M. persicae* > *A. nerii*.

KEYWORDS: *Micraspis discolor*, Coccinellids, Prey preference, Aphids.

Coccinellids are potential predators of small and soft bodied insect pests (*viz* aphids, mealy–bugs, scale–insects, *etc.*) of agricultural crops. Of the coccinellids, *Micraspis (=Verania) discolor* (Fabricius) is most abundant in Uttar Pradesh and is a voracious predator of aphids (Omkar and Bind, 1993). It possesses distinct sexual dimorphism (Omkar and Bind, 1996; Omkar and Pervez, 2000). A perusal of literature reveals that though some work on its biology and feeding behaviour has been done by the earlier workers (Jiang and Su, 1985; Agarwala *et al*, 1988; Prodhan *et al*, 1995), studies on the choice of its prey are still wanting. Keeping in view these informations and its bioefficacy as a biocontrol agent, an attempt has been made to evaluate the prey–preference of the ladybeetle, *M. discolor* amongst nine aphid preys.

Adults and grubs of *M. discolor* were collected from the agricultural fields adjoining the city of Lucknow and brought to the laboratory. The stock cultures were maintained at $25°C \pm 2°C$ and $60 \pm 5\%$ R.H. on aphids along with their host twigs in circular glass troughs (diameter 20 cm and height 20 cm) covered with muslin cloths. Nine aphids, *viz Aphis craccivora* Koch, *Aphis gossypii* Glover, *Aphis nerii* Boyd., *Brevicoryne brassicae* (Linnaeus), *Lipaphis erysimi* (Kaltenbach), *Melanaphis bambusae* (Zehnter), *Myzus persicae* (Sulzer), *Rhopalosiphum maidis* (Fitch), and *Uroleucon compositae* (Theobald) were collected from the agricultural fields infesting *Dolichos lablab, Lagenaria vulgaris, Calotropis procera, Brassica*

*Corresponding author

TABLE 1. Prey consumption per female adult *M. discolor* within 24 h. Values are expressed in Mean±SD.

Name of aphid prey	No. of prey consumed
Aphis gossypii	64.33 ± 4.80
Aphis craccivora	54.50 ± 4.51
Melanaphis bambusae	52.17 ± 5.56
Lipaphis erysimi	47.33 ± 3.50
Uroleucon compositae	45.67 ± 2.66
Brevicoryne brassicae	42.67 ± 2.34
Rhopalosiphum maidis	40.33 ± 4.23
Myzus persicae	39.00 ± 1.90
Aphis nerii	17.83 ± 2.32
CD at 5% = 4.47; CD at 1% = 5.84	($F = 70.86$; $P < 0.01$)

oleracea var. *capitata, Brassica juncea, Bambusa* sp., *Solanum tuberosum, Zea mays*, and *Chrysanthemum* sp. respectively, on the day of commencement of the experiments. One 12 hours starved healthy adult female beetle was kept in a beaker (diameter 7.5 cm and height 10 cm) containing 100 aphids along with the fresh twig of the respective host plant. The open end of the beaker was covered with a muslin cloth. The unconsumed aphids were counted after 24 hours to record the number of aphids consumed. The experiment was similarly designed for all the nine aphids. The experiment was performed in six replicates and the data were subjected to statistical analysis (Snedecor and Cochran, 1966).

The data presented in Table 1 revealed that the adult female *M.discolor* consumed 64.33 ± 4.80, 54.50 ± 4.51, 52.17 ± 5.56, 47.33 ± 3.50, 45.67 ± 2.66, 42.67 ± 2.34, 40.33 ± 4.23, 39.00 ± 1.90, 17.83 ± 2.32 adults of *A. gossypii, A. craccivora, M. bambusae, L. erysimi, U. compositae, B. brassicae, R. maidis, M. persicae* and *A. nerii*, respectively in 24 hours. The maximum consumption was observed on the aphid, *A. gossypii*. The ladybeetle shows a considerable preference to aphids, *A. craccivora* and *M. bambusae*. The other aphids, *viz. L. erysimi, U. compositae, B. brassicae, R maidis* and *M. persicae* were also consumed but at a slower rate. Aphid, *A. nerii* was least preferred. The order of preference was *A. gossypii* > *A. craccivora* > *M. bambusae* > *L. erysimi* > *U. compositae* > *B. brassicae* > *R. maidis* > *M. persicae* > *A. nerii*. The statistical analysis of data revealed Critical Difference at 5% and 1% levels to be 4.47 and 5.84 respectively. The differences in the mean number of aphids consumed were statistically highly significant ($F = 70.86$; $P < 0.01$).

The ladybeetle, *Anegleis cardoni* (Wiese) preferred *B. brassicae* the most and *A. gossypii* the least (Afroze, 1999). The other ladybeetles, *C. septempunctata* had a high preference for *Hyadaphis coriandri, M. persicae* and *B. brassicae* (Omkar *et al*, 1997), *C. transversalis* for *A. craccivora* (Omkar *et al*, 1999) and *Cheilomenes sexmaculata* for *A. gossypii* (Omkar and Bind, 1998). *A. nerii* was least preferred by all the ladybeetles (Omkar *et al*, 1997, 1999; Omkar and Bind, 1998). The other workers have reported a high preference of *C. septempunctata* for *L. erysimi* (Aziz *et*

al, 1969; Srivastava *et al*, 1978). The adults and grubs of *C. repanda (=transversalis)* preferred *A. gossypii* and *L. erysimi* (Srivastava *et al*, 1982).

Preference of the ladybeetles for certain aphid species might be due to the variation in food quality caused by difference in the chemical constituents present in aphid infested host plants. Since, *A. gossypii* and *A. craccivora* were preferred more, the investigation provides a basic evidence for the exploration of *M. discolor* to minimise the infestation of these aphids.

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REFERENCES

Afroze, S. (1999) Preferential predation by *Anegleis cardoni* (Weise) (Coccinellidae: Coleoptera) on some aphid species, *J. Aphidol.* **13**: 95–97.

Agarwala, B. K., Das, S. and Senchowdhuri, M. (1988) Biology and food relations of *Micraspis discolor* (F.). An aphidophagous coccinellid in India, *J. Aphidol.* **2**(1&2): 7–17.

Aziz, S. A., Hyder, S. N. and Ali, M. H. (1969) Studies on the host preference of *Coccinella septempunctata* Linn., *Indian J. Entomol.* **31**(4): 350–353.

Jiang, Y. C. and Su, Z. M. (1985) A discussion on the systematic status of *Verania discolor* (Fabricius) with reference to its feeding behaviour, *Acta Entomol. Sinica* **28**(1): 115–117.

Omkar and Bind R. B. (1993) Records of aphids-natural enemies complex of Uttar Pradesh. II. The Coccinellids, *J. Adv. Zool.* **14**(2): 96–99.

Omkar and Bind R. B. (1996) Sexual dimorphism in a ladybird beetle, *Micraspis discolor* (Fabricius), *Agric. Sci. Digest* **16**(1): 42–44.

Omkar and Bind R. B. (1998) Prey preference of a ladybird beetle, *Cheilomenes (=Menochilus) sexmaculata* (Fabr.), *J. Aphidol.* **12**: 63–66.

Omkar and Pervez A. (2000) Well marked sexual dimorphism in a ladybird beetle, *Micraspis discolor* (Fabricius) (Coccinellidae: Coleoptera), *Insect Environ.* **5**(4): 150–151.

Omkar, James B. E. and Srivastava S. (1999) Prey preference of a ladybeetle, *Coccinella transversalis* Fabricius (Coleoptera : Coccinellidae), *Adv. Bios.* **18**(2): 117–122.

Omkar, Srivastava S. and James B. E (1997) Prey preference of a ladybeetle, *Coccinella septempunctata* Linnaeus (Coleoptera : Coccinellidae), *J. Adv. Zool.* **18**(2): 96–97.

Prodhan, M. Z. H., Haque, M. A., Khan, A. B. and Rahman, A. K. M. M. (1995) Biology of *Micraspis discolor* (F.) (Coleoptera: Coccinellidae) and its susceptibility to two insecticides, *Bangladesh J. Entomol.* **5**(1–2): 11–17.

Srivastava, A. S., Katiyar, R., Upadhyay, K. D. and Singh, S. V. (1982) Studies on the host preference of *Coccinella repanda* Thunberg (Coleoptera: Coccinellidae), *Indian J. Entomol.* **49**(4): 551–552.

Srivastava, A. S., Upadhyay, K. D., Mishra, B. P. and Katiyar, R. R. (1978) Prey preference of *Coccinella septempunctata* (L.) (Coleoptera: Coccinellidae), *Indian J. Agric. Sci.* **48**(2): 84–86.

Snedecor, G. W. and Cochran, W. G. (1996) *Statistical Methods*, Oxford & IBH Publishing Co: New Delhi, 593.

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